Biofuels Extraction through Pyrolysis of Plastic Waste & Rubber Waste Mixture

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Abstract

The increasing global generation of plastic and rubber waste poses significant environmental challenges, prompting the exploration of sustainable waste management strategies. Pyrolysis, a thermochemical conversion process, emerges as a promising technology for the effective recycling of these non-biodegradable materials. This study investigates the pyrolysis decomposition of plastic and rubber waste, focusing on the transformation of complex hydrocarbons into valuable products.

The pyrolysis process involves subjecting the waste materials to elevated temperatures in the absence of oxygen, leading to the breakdown of polymer chains. The resulting products include liquid fuels, such as pyrolysis oil, which can serve as an alternative to conventional fossil fuels. Gaseous byproducts, including hydrogen and methane, can be captured and utilized for energy production. Additionally, solid residues, known as char, may find applications in various industries or as a source of carbon for soil improvement.

This abstract discusses key parameters influencing the pyrolysis process, such as temperature, residence time, and catalysts, and their impact on product yields and quality. Environmental considerations and techno-economic aspects are also addressed to evaluate the sustainability and feasibility of pyrolysis as a waste-to-energy solution. The findings suggest that pyrolysis of plastic and rubber waste holds significant potential for resource recovery, providing an environmentally sound method for converting waste into valuable energy products and reducing the reliance on conventional fossil fuels. Further research and development in process optimization and scale-up are essential for maximizing the benefits of this technology in the transition towards a circular economy.

TABLE OF CONTENTS

CHAPTER-I INTRODUCTION			page no
1.1	:	Introduction	07
1.2	:	Objectives	08
CHAPTER-II LITARATURE REVIEW			
2.1	:	Historical Background	09
2.2	:	Plastic Waste Bio-Fuel	11
2.3	:	Advantage of pyrolysis oil	11
2.4	:	Disadvantage of pyrolysis oil	12
2.5	:	Plastic Waste	13
2.6	:	Plastic Waste Disposal	16
2.7	:	Pyrolysis	17
2.8		Types of pyrolysis	17
2.9		Fast pyrolysis	17
2.10		Slow pyrolysis	18
2.11		Flash pyrolysis	18
2.12	:	Properties of pyrolytic oil	18
2.13	:	Application of pyrolytic oil	19
2.14	:	Pyrolysis Economics	19
2.15	:	Limitation of plastic waste fuel	20
CHAPTER-III THEORITICAL ASPECTS			
3.1	:	Plastic Waste Fundamentals	21

2.2 : Pyrolysis Principle 22

CHAPTER-IV DESIGN AND CONSTRUCTION OF APPARATUS page no

4.1 : System components 23

4.2 : Pyrolysis Reactor 23

4.3 : Temperature sensing element 23

4.4 : Heating arrangement 24

4.5. : Condenser arrangement 25

4.6. : CAD design of apparatus 25

4.7 : Final constructed Apparatus 26

4.8 : Final collected output 27

CHAPTER-V RESULT AND DISCUSSION

5.1 : Experimental data 28

5.2 : Relative amount of output 29

5.3 : Properties of obtained liquid 29

CHAPTER VI CONCLUSION

6.1 : Conclusion 30

6.2 : Scope of future work 31

6.3 : Discussion 32

6.4 : References 33

List of Figure no. Page no

2.1 : Schematic diagram showing Fast pyrolysis product distribution 9

2.2 : Schematic diagram showing slow pyrolysis product distribution 11

2.1 : Applications of pyrolysis product (pyrolysis oil) 11

3. : Flow diagram of pyrolysis process of plastic waste 21

4.1.1 : Schematic drawing of reactor shell 23

4.1.2 : Temperature sensing element 23
4.1.3 : Gas turbine 24
4.1.4 : Condenser arrangement 25
4.1.5 : Design of pyrolysis apparatus 23
4.1.6 : Final constructed apparatus 26
4.1.7 : Final collected output 27

List of Tables Table no.

5.1 : Experimental data 28
5.2 : Relative number of outputs 29
5.3 : Properties of obtained fuel 29

Chapter I

Introduction

1.1: Introduction:

In recent decades, the escalating global production of plastic and rubber materials has led to a significant surge in waste generation, posing formidable challenges to waste management and environmental sustainability. Traditional disposal methods such as landfilling and incineration have proven to be environmentally detrimental, contributing to soil and water pollution, air quality degradation, and the depletion of valuable resources. Consequently, there is an urgent need for innovative and sustainable waste management strategies to address this burgeoning crisis.

Pyrolysis, a thermochemical conversion process, emerges as a promising solution to transform plastic and rubber waste into valuable products, including liquid fuels, gases, and solid char. This process involves the thermal decomposition of organic materials in the absence of oxygen, leading to the generation of useful by-products while mitigating the adverse environmental impacts associated with conventional disposal methods.

This thesis aims to explore the feasibility and potential benefits of conducting pyrolysis on a mixture of plastic and rubber waste. By combining these two types of waste, which share similarities in their chemical composition, the objective is to enhance the efficiency and versatility of the pyrolysis process. The synergistic effects of co-processing plastic and rubber waste can lead to improved product yields, reduced energy consumption, and a more sustainable approach to waste management.

The escalating global consumption of plastic and rubber products has given rise to an unprecedented challenge of managing the vast volumes of waste generated from these materials. The persistence of plastic and rubber waste in the environment, coupled with its adverse impact on ecosystems, human health, and aesthetics, has spurred a pressing need for sustainable waste management solutions. Pyrolysis, a thermochemical conversion process, presents itself as a promising technology for addressing this environmental predicament by transforming plastic and rubber waste into valuable products.

Pyrolysis involves the thermal decomposition of organic materials in the absence of oxygen, leading to the production of gas, liquid, and solid byproducts. The process holds immense potential for mitigating the environmental impact of plastic and rubber waste by converting them into useful resources such as fuel, chemicals, and energy. This thesis delves into the pyrolysis of plastic and rubber waste, exploring its technical feasibility, environmental implications, and economic viability.

The exploration of pyrolysis as a waste management strategy becomes crucial in light of the limitations and challenges associated with traditional disposal methods, including landfilling and incineration. These conventional methods contribute to pollution, resource depletion, and

greenhouse gas emissions, exacerbating the already critical issues of climate change and environmental degradation. Pyrolysis offers an alternative route, providing a closed-loop solution that can potentially contribute to a more circular economy, wherein the value of plastic and rubber waste is maximized through their conversion into valuable end-products.

This thesis aims to comprehensively investigate the pyrolysis process, evaluating its efficiency, environmental impact, and the quality of the end-products obtained from plastic and rubber waste. By analyzing the technical aspects of pyrolysis and its potential as a waste-to-energy technology, this research endeavors to contribute valuable insights to the ongoing discourse on sustainable waste management.

Year	Production plastic every year (tones)	Waste every year plastic (tones)
2020-21	390 million tones	7.69 million tones
2021-22	391 million tones	8.10 million tones
2022-23	400 million tones	8.47 million tones

Table no 1: Annual production of plastic in year 2020-21 to 2022-23

Year	Production rubber every year (tones)	Waste of rubber every year (tones)
2020-21	27.4 million tones	1.4 million tones
2021-22	29.6 million tones	1.7 million tones
2022-23	14.3 million tones	1.1 million tones

Table no 1: Annual production of rubber in year 2020-21 to 2022-23

1.2: Objectives

The objectives of this project work are:

i. To Design and construction of a pyrolysis apparatus.
ii. To Extraction bio-fuel from Plastic waste & Rubber waste.
iii. To analyze properties (density, viscosity, gross calorific value, flash point, pour point) of obtained biofuel.

Chapter: II

Historical Background

2.1: Historical Background

The development of plastic materials started with the use of natural materials with plastic properties then evolved with the development of chemically modified natural materials (e.g., rubber, nitrocellulose, collagen) and finally the wide range of completely synthetic material that we would recognize as modern plastics started to be developed around 100 years ago.

In the world a total of over 100 million tons of plastic is manufactured to meet global plastic demand. This much production and consumption of plastic is a threat to environment as it takes several years to decompose naturally. According to ASTM (American Society for Testing and Materials) plastic recycling methods are of four types on the basis of final products. The tertiary or chemical recycling degradation is one of the categories. From this method of chemical degradation, liquid fuels and high value added chemicals are produced by waste plastic fragments. One of tertiary recycling method is pyrolysis.The first man-made plastic was created by Alexander Parkes at the 1862 Great International Exhibition in London. Today known as celluloid, the material was called Parkesine derived from cellulose that once heated could be molded, and retained its shape when cooled. In 1907 Leo Baekeland created Bakelite, the first synthetic mass-produced plastic. In 1933, polyethylene was discovered by Imperial Chemical Industries (ICI). From the 1940's onwards, a range of other plastics were discovered and became mass produced for a wide range of existing and new applications.After a number of experiments with parkesina, the American typographer John Wesley Hyatt patented the celluloid in 1869. To push him in the research of this new material was a tender promoted by the company Phelan and Collander, manufacturer of billiard balls, in which a ten thousand dollars reward was offered to whom would had been able to develop a substance replacing ivory, which was becoming scarce. Firstly, celluloid was widely used by dentists as a substitute of the expensive vulcanised rubber for getting dental records.[3].The appearance of a new material, the bakelite, overshadowed the success of the first artificial plastic materials. This new material will dominate the world of plastic for half a century.Bakelite was invented by the Belgian chemist Leo Hendrick Baekeland in 1907. Bakelite was the first thermosetting resin obtained by the reaction of phenol and formaldehyde. By this reaction, we get a resinous product that

becomes plastic when heated. Under these conditions, the material can be pressed into moulds in order to get objects of various shapes. By extended the heating into the mould, the material hardens and maintains the shape given permanently.[4] Bakelite can be coloured and polished, therefore it was soon used for manufacturing domestic electrical appliances, toys, boxes, jewellery, lamps but also car dashboards. Nowadays this plastic is used as an electric insulation material and for pot handles In 1913 the Swiss Jacques Edwin Brandenberger invented the cellophane, a cellulose-based material produced in very thin and flexible sheets. It is a transparent and impermeable material which is soon applied in the packaging field. The word cellophane, by now in common usage, coined by its inventor, was created by combining the words "cellulose" and "diaphane" (letting the light pass through and see through it).In the '20s began the first attempts to create plastic material from oil as "raw material". In 1935 the American chemist Wallace Carothers synthesized, at a chemical laboratory of Dupont, the textile fibre today known as nylon (polyamide). This material marked the rising of "synthetic fibres" and will be largely used in the textile industry: from tights to parachutes. A few years later Rex Whinfield and James Tennant Dickson patented in England the polyethylene terephthalate (PET). The use of PET spread after the Second World War and it was used for making parachutes, sweaters and shirts that do not have to be ironed. This material entered the world of food packaging in1973, when the inventor and prolific American engineer Nathaniel Wyeth (Du Pont), undertook the challenge of finding a way to produce ginger bottles without using the glass. According to Wyeth it was a challenge that was won only after years of tests, patenting in 1977 a new method of producing plastic bottles. His solution consisted in using a special mould able to lengthen the fibres so that the molecules would align making the material stronger. The bottle invented by Wyet, which was light, impact-resistant and transparent, is nowadays the standard for mineral water and drinks packaging.The "years of plastic" began officially the 11th March 1954, when Giulio Natta, future Nobel Prize for Chemistry (in 1963), wrote in his diary: «Made the polypropylene».The new product, later called "Moplen", was used for producing everything: from dishes to car components to bowls and toys.During the "economic miracle" in the 60's, plastic invaded Italian people's home with objects that look polish, smooth, modern and above all coloured. These objects were available at an "affordable" price and no longer for the sole rich people.From "mass" plastic material we arrived at the so-called technopolymers or polymers for engineering, having resistance and rigidity features such as to use them instead of the traditional metals. One of these is the polycarbonate. Its performances are higher than average and it is used in several fields such as: optics for spectacle lenses,

transport for helmets and light covers, military for bulletproof vests and riot shields, buildings for coverings and windows etc…Although plastic is now recognised as a “mature” material, the 90’s have been marked by important technical developments in order to meet needs which are constantly increasing in modern manufacturing[5].

2.2: Plastic waste bio-fuel:

Pyrolysis is a process that involves the thermal decomposition of organic materials at elevated temperatures in the absence of oxygen. This process is commonly used for the treatment of plastic and rubber waste to convert them into biofuel.

Plastic and rubber waste refers to discarded materials made from polymers, such as polyethylene, polypropylene, PVC (polyvinyl chloride), and rubber compounds. These materials are commonly found in various products like packaging, containers, tires, and other goods.

2.3: Advantages of plastic waste bio-fuel:

Pyrolysis helps convert non-biodegradable plastic and rubber waste into valuable biofuels, thus reducing the environmental impact of these materials.

Energy Recovery: The process generates biofuels such as pyrolysis oil, syngas, and char, which can be used as alternative energy sources. This contributes to energy recovery and reduces dependence on fossil fuels.

Waste Reduction: Pyrolysis provides a method to manage and dispose of plastic and rubber waste that might otherwise end up in landfills or contribute to pollution.

Lower Greenhouse Gas Emissions: Biofuels produced from pyrolysis typically have lower greenhouse gas emissions compared to traditional fossil fuels, contributing to climate change mitigation.

Versatility of Feedstock: Pyrolysis can be applied to a variety of plastic and rubber materials, providing flexibility in the types of waste that can be converted into biofuels.
Carbon Neutral Potential: If the feedstock comes from renewable sources or is sourced sustainably, the overall carbon footprint of the biofuels produced through pyrolysis can be relatively low.
Byproduct Utilization: Byproducts such as char and syngas can be utilized for various purposes, such as soil amendment or as a source of additional energy.

2.4: Disadvantages:

Emissions and Air Quality: Pyrolysis can release various pollutants into the air, including volatile organic compounds (VOCs) and particulate matter. Depending on the feedstock and operating conditions, the emissions may contribute to air pollution and have negative effects on local air quality.

Energy Intensive: The pyrolysis process itself can be energy-intensive, especially if high temperatures are required to break down complex polymers. If the energy input is derived from non-renewable sources, it may offset some of the environmental benefits of using biofuels.

Variable Feedstock Quality: The quality and composition of plastic and rubber waste can vary widely, affecting the efficiency and yield of biofuel production. Contaminants or mixed materials may reduce the quality of the biofuel and increase the difficulty of the refining process.

Residue and Waste Management: Pyrolysis does not eliminate waste entirely; it produces byproducts, such as char or ash, which require proper disposal or management. The handling and disposal of these residues can pose environmental challenges if not managed responsibly.

Limited Feedstock Supply: The availability of consistent and high-quality plastic and rubber waste may be limited. This limitation could affect the scalability and long-term sustainability of pyrolysis-based biofuel production.

Technical Challenges: Pyrolysis technology faces certain technical challenges, such as the need for catalysts and the potential for reactor fouling. Addressing these issues can require additional research and development efforts.

Economic Viability: The economic viability of pyrolysis as a waste-to-biofuel solution may be influenced by factors such as the cost of feedstock collection, processing, and the market price of competing energy sources. If these factors are not favorable, the economic feasibility of pyrolysis projects may be compromised.

Limited Range of Products: Pyrolysis typically produces a mixture of hydrocarbons, which may be limited in terms of the types of fuels that can be derived. The range of usable biofuels may not be as diverse compared to other biomass conversion processes.

2.5: Plastic Waste:

Plastic includes materials composed of various elements such as carbon, hydrogen, oxygen, nitrogen, sulphur. Plastic are macromolecules formed by polymerization and having the ability to be shaped by the application of reasonable amount of heat and pressure and any other force. Polyethylene, polyvinylchloride and polystyrene are largely used in manufacturing of plastic [6].

The seven types of plastic include:

Polyethylene Terephthalate (PETE or PET)

High-Density Polyethylene (HDPE)

Polyvinyl Chloride (PVC)

Low-Density Polyethylene (LDPE)

Polypropylene (PP)

Polystyrene or Styrofoam (PS)

There are seven types of different plastic you should know about.

Polyethylene Terephthalate (PETE or PET)

Polyethylene Terephthalate (PETE or PET) is a widely utilized thermoplastic polymer within the polyester family, renowned for its transparency and clarity. Its recyclability, denoted by the recycling code "1," makes PETE an environmentally friendly choice. Commonly found in beverage containers due to its lightweight nature, PETE is durable and chemically resistant, making it suitable for various packaging applications. Beyond its role in packaging, PETE extends its versatility to clothing fibers (polyester clothing) and diverse industrial applications. While appreciated for its temperature resistance in typical scenarios, caution is warranted in high-temperature environments. The environmental impact of PETE production involves fossil fuels, underscoring the importance of proper recycling to mitigate ecological concerns. Overall, PETE stands as a versatile and widely employed polymer with applications ranging from everyday packaging to industrial uses.

High-Density Polyethylene (HDPE)

High-Density Polyethylene (HDPE) is a thermoplastic polymer characterized by its high strength-to-density ratio. Known for its robustness and versatility, HDPE belongs to the polyethylene family and is widely used in various applications. With a high resistance to chemicals and impact, HDPE finds extensive use in packaging, including bottles, containers, and bags. Its durability and low moisture absorption make it suitable for outdoor and construction applications, such as pipes, geomembranes, and plastic lumber. HDPE is also recognized for its recyclability, denoted by the recycling code "2," contributing to its eco-friendly profile. As a result of its excellent tensile strength and resistance to wear, HDPE is often employed in products designed for long-term use, ranging from toys to medical devices. Its versatility, recyclability, and durability make HDPE a widely chosen material in various industries, offering solutions that balance performance and environmental considerations.

Polyvinyl Chloride (PVC)

Polyvinyl Chloride (PVC) is a versatile thermoplastic polymer widely used for its durability and chemical resistance. It is commonly employed in construction materials like pipes, fittings, and siding due to its strength and low cost. PVC is also prevalent in the production of clothing, inflatable structures, and electrical cables. Recognized by the recycling code "3," PVC can be recycled, though there are environmental considerations due to the release of

chlorine during its production. While PVC offers diverse applications, its environmental impact has led to discussions about alternatives and responsible disposal practices.

Low-Density Polyethylene (LDPE)

Low-Density Polyethylene (LDPE) is a flexible and lightweight thermoplastic polymer with a lower density than its high-density counterpart, HDPE. LDPE is commonly used for its excellent flexibility, making it suitable for packaging films, plastic bags, and various squeezable containers. Its resistance to moisture and chemicals, along with its ease of process ability, contribute to its popularity in packaging applications. While not as rigid as HDPE, LDPE offers impact resistance and is commonly used for products like six-pack rings, agricultural films, and tubing. Additionally, LDPE is recyclable (recycling code "4"), adding to its appeal as a versatile and adaptable material in a range of everyday products.

Polypropylene (PP)

Polypropylene (PP) is a versatile thermoplastic polymer known for its durability, chemical resistance, and wide range of applications. As a member of the polyolefin family, PP is characterized by its lightweight nature and high melting point, making it suitable for diverse industries. It is commonly used in packaging, including containers, caps, and films, due to its excellent barrier properties. PP's resistance to moisture and chemicals makes it ideal for applications in the food and pharmaceutical industries. The material is also used in textiles, automotive components, and medical devices. PP is known for its recyclability (recycling code "5") and is considered an environmentally friendly option. Its ability to withstand high temperatures without losing its integrity adds to its appeal, making polypropylene a preferred choice in numerous manufacturing processes and consumer products.

Polystyrene or Styrofoam (PS)

Polystyrene (PS), commonly known by the brand name Styrofoam, is a versatile thermoplastic polymer widely used for its lightweight, insulating, and cost-effective properties. It is popular in packaging, disposable food containers, and insulation materials. Expanded Polystyrene (EPS), often referred to as Styrofoam, is a lightweight foam variant of polystyrene known for its excellent insulation capabilities. Despite its utility, concerns have been raised about its environmental impact, as it is not easily biodegradable. Efforts are being

made to increase recycling rates and explore alternative materials. In addition to packaging, PS is used in disposable cups, trays, and as a component in various consumer goods. Understanding its benefits and challenges is crucial for responsible use and disposal.

2.6: Plastic Waste Disposal:

The three main methods of plastic disposal.

Landfilling:

Landfilling is a waste disposal method where solid waste is buried in designated areas. Despite engineering measures to reduce environmental impact, concerns exist about groundwater and air pollution. Decomposing waste in landfills generates methane, a potent greenhouse gas. Efforts to increase recycling and explore alternative waste management methods aim to minimize reliance on landfilling for a more sustainable approach.

Incineration:

Incineration is a waste disposal method involving the combustion of solid waste at high temperatures. This process reduces the volume of the waste and produces heat and, often, electricity. Incineration can be more environmentally friendly than traditional landfilling, as it minimizes space requirements and can generate energy. However, concerns include air emissions, such as pollutants and greenhouse gases. Advanced technologies and strict regulations aim to mitigate these impacts. Incineration is often used for municipal solid waste and certain hazardous wastes, contributing to waste reduction and energy recovery efforts

Recycling:

Recycling is a sustainable waste management practice that involves collecting, processing, and reusing materials from discarded items instead of disposing of them as waste. The process typically includes the sorting and separation of recyclable materials, such as paper, glass, plastic, and metal, followed by processing to create new products. Recycling helps conserve natural resources, reduce energy consumption, and decrease the volume of waste sent to landfills. It plays a crucial role in promoting a circular economy by extending the life cycle of materials. Community participation, proper waste segregation, and support for recycling infrastructure are essential for the success of recycling programs and achieving environmental sustainability.

2.7: Pyrolysis:

Pyrolysis is a thermal decomposition process that involves the heating of organic materials in the absence of oxygen, leading to the breakdown of complex molecules into simpler compounds, such as gases, liquids, and solids. This process occurs at elevated temperatures, typically ranging from 300 to 900 degrees Celsius. The absence of oxygen prevents combustion, and the resulting products can be used for various purposes.

In the context of waste management, pyrolysis is often employed as a technology to treat certain types of organic waste, plastics, and biomass. The end products can include biochar, liquid biofuels, and syngas. Pyrolysis has gained attention for its potential to convert waste materials into valuable resources, reduce the environmental impact of waste disposal, and contribute to renewable energy production. However, challenges such as technology efficiency, cost-effectiveness, and the need for proper waste feedstock selection need to be addressed for widespread adoption and sustainability.

2.8: Types of pyrolysis:

The process pyrolysis occurs in three different ways, based on temperature range there are three types of pyrolysis process.

1. Fast pyrolysis
2. Slow pyrolysis
3. Flash Pyrolysis

2.9: Fast pyrolysis:

Fast pyrolysis is a thermal decomposition process that rapidly heats organic materials, such as biomass, at high temperatures (400-600°C) in the absence of oxygen. The short residence time results in the quick production of bio-oil, gases, and solid char.

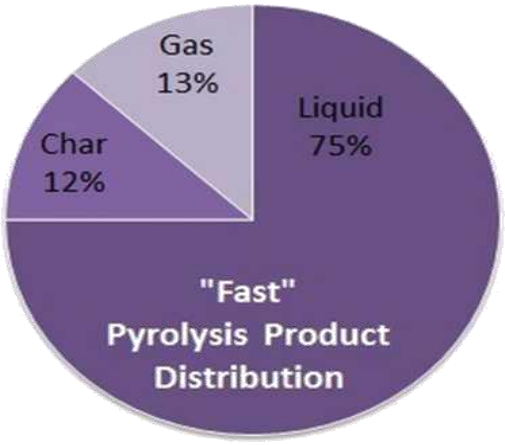


Fig 2.1: Schematic diagram showing Fast pyrolysis product distribution

2.10: Slow pyrolysis:

Slow pyrolysis is a thermal decomposition process in which organic materials, like biomass, are gradually heated at lower temperatures (below 450°C) in the absence of oxygen. This slower heating rate and longer residence time lead to the production of biochar, bio-oil, and gases.

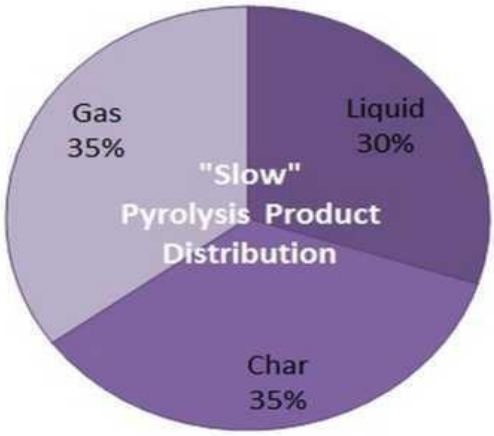


Fig 2.2: Schematic diagram showing slow pyrolysis product distribution.

2.11: Flash Pyrolysis:

Flash pyrolysis is an intermediate pyrolysis process that involves the rapid heating of organic materials, typically at moderate temperatures (450-600°C), in the absence of oxygen. It results in a shorter residence time than slow pyrolysis and produces bio-oil, gases, and char.

2.12: Properties of pyrolytic oil:

Pyrolytic oil, also known as bio-oil, is a liquid product obtained through the pyrolysis of organic materials like biomass or wood. Its properties play a crucial role in determining its suitability for various applications.

Density (ρ):

Density is the mass per unit volume.

Density ρ = Mass / Volume (kg/m3)

Gross Calorific Value (GCV):

GCV is the amount of heat released during the complete combustion of a unit mass of fuel.

The GCV is often measured experimentally using calorimetry, and the unit is typically expressed in joules per gram or kilojoules per kilogram.

Flash Point:

The flash point is the lowest temperature at which the vapor of a substance can ignite.

Pour Point: The pour point is the lowest temperature at which a fluid remains pourable.

Viscosity (η):

Viscosity measures a fluid's resistance to flow.

Kinematic viscosity $\nu = 0.22t - 135$/ Absolute viscosity $\mu = \nu * \rho$

The relationship between shear stress and shear rate provides information about the fluid's flow behavior.

2.13: Application of pyrolysis oil:

The bio-oil obtained from pyrolysis can have the following industrial applications:

- Combustion of fuel
- power generation
- extraction of chemicals and resins
- production of laevoglucose
- binding agents

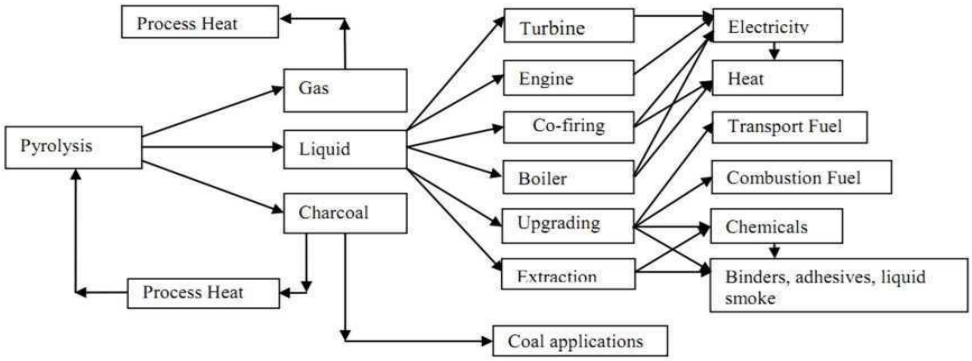


Fig 2.2: Applications of pyrolysis product (pyrolysis oil)

2.14: Pyrolysis Economics:

Pyrolysis, from an economic perspective, represents a promising avenue for sustainable waste management and the production of valuable resources. The economic viability of pyrolysis processes depends on several factors, including the type of feedstock, scale of operation, technology efficiency, and the market demand for the end products. Pyrolysis has the potential to generate revenue through the production of biofuels, biochar, and other valuable chemicals. Additionally, the reduction in landfill costs and the potential to earn carbon credits contribute to the economic attractiveness of pyrolysis. However, challenges such as initial capital investment, operational costs, and the need for market development for pyrolysis products must be carefully considered. As technology advances and regulatory frameworks evolve to support sustainable practices, the economic landscape for pyrolysis is likely to become increasingly favorable, fostering its integration into a circular economy model. Governments, investors, and industries are showing growing interest in the economic potential of pyrolysis as a key contributor to both waste reduction and the production of renewable resources.

2.15: Limitation of plastic waste fuel:

The utilization of plastic and rubber waste as fuel presents an innovative approach to waste management and energy recovery. However, this practice is not without its limitations. One primary concern is the potential release of harmful emissions during the combustion of these materials. Plastic and rubber waste often contain additives, pigments, and other substances that can produce pollutants when burned, contributing to air pollution and posing health risks. Additionally, incomplete combustion may lead to the generation of toxic by-products. Another limitation lies in the variability of the feedstock. The composition of plastic and rubber waste can be diverse, making it challenging to achieve consistent and predictable combustion characteristics. This variability can affect combustion efficiency and the overall performance of waste-derived fuels. Furthermore, the economic viability of large-scale implementation is influenced by the costs associated with collecting, sorting, and processing diverse waste streams. Despite these limitations, ongoing research and technological advancements aim to address environmental concerns and improve the efficiency of plastic and rubber waste utilization as a fuel source. Balancing the benefits of waste reduction and energy recovery with the need for stringent emission controls remains a crucial challenge in harnessing the potential of plastic and rubber waste as a sustainable fuel alternative.

Chapter: III

THEORITICAL ASPECTS

3.1: Plastic waste Fundamentals:

The utilization of plastic and rubber waste as fuel involves the application of innovative technologies to address environmental concerns and energy needs. Plastics and rubber, both derived from hydrocarbons, possess a significant calorific value, making them potential energy sources. The fundamental concept lies in converting these non-biodegradable materials, which often end up in landfills, into a valuable energy resource. Various methods, such as pyrolysis or gasification, are employed to break down the complex polymers into combustible gases, liquids, or solid fuels. Through these processes, the energy stored in the chemical bonds of plastics and rubber is harnessed for electricity generation or other thermal applications. This not only provides an alternative to traditional fossil fuels but also addresses the critical issue of plastic pollution. While the conversion of plastic and rubber waste into fuel holds promise for sustainable energy solutions, challenges remain in optimizing conversion processes, managing emissions, and ensuring economic viability. The ongoing research and development in this field aim to establish efficient and environmentally friendly approaches to derive energy from plastic and rubber waste, contributing to both waste management and energy sustainability goals.

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3.2: Pyrolysis principle:

Pyrolysis is a thermochemical decomposition process that applies high temperatures in the absence of oxygen to convert plastic and rubber waste into valuable fuel. The principle behind pyrolysis involves breaking down complex polymer chains of plastics and rubbers into simpler hydrocarbons, gases, and char through the application of heat. In the absence of oxygen, the process prevents combustion, allowing the materials to undergo thermal degradation. Plastic and rubber waste, which are traditionally challenging to recycle due to their complex structures and potential environmental impact, find a sustainable disposal solution through pyrolysis. The waste is fed into a pyrolysis reactor, where it is heated to elevated temperatures, typically between 300 and 900 degrees Celsius. At these temperatures, the polymers undergo thermal cracking, resulting in the formation of pyrolytic oil, syngas, and solid char. The pyrolytic oil is a valuable liquid product that can be further refined into fuels, while the syngas is composed of combustible gases suitable for energy generation. The solid char, often referred to as biochar, can be used for various applications, including soil amendment. Pyrolysis of plastic and rubber waste not only provides an environmentally sound waste disposal method but also contributes to the production of renewable fuels, thereby addressing both waste management and energy sustainability challenges. However, challenges such as optimizing process efficiency, minimizing environmental emissions, and ensuring economic viability continue to be areas of research and development in the advancement of pyrolysis technology for plastic and rubber waste.

Chapter: IV

DESIGN AND CONSTRUCTION OF APPARATUS

4.1: System components:
The main system components are described below:

4.2: Pyrolysis Reactor: Utilizing steel containers as pyrolysis reactors heated by induction technology represents an innovative fusion of materials and heating methods in the pursuit of sustainable waste management. The inherent strength and durability of steel containers make them ideal vessels for withstanding the rigors of the pyrolysis process. When paired with induction heating, an efficient and precise method that relies on electromagnetic induction to generate heat directly within the container's walls, these reactors become capable of reaching and maintaining the high temperatures required for effective thermal decomposition.



Figer:4.1: Drawing of reactor sells.

4.3: Temperature sensing element: The temperature inside the reactor is measured by a thermocouple. The thermocouple was K type thermocouple. Type K (Chromel-Alumel) is the most common general purpose. Thermocouple. It is inexpensive available in a wide variety of probes. They are available in the −200 °C to +1350 °C range. The range of thermocouple used for this experiment is 0oC to 800oC.



Figer:4.2: Temperature sensing meter

4.4: Heating Arrangement or Process: Three U shaped electrical dry heaters are mounted on the top part of the reactor. Each heater is 1000W and 220V. Heater provides heat for thermal decomposition.



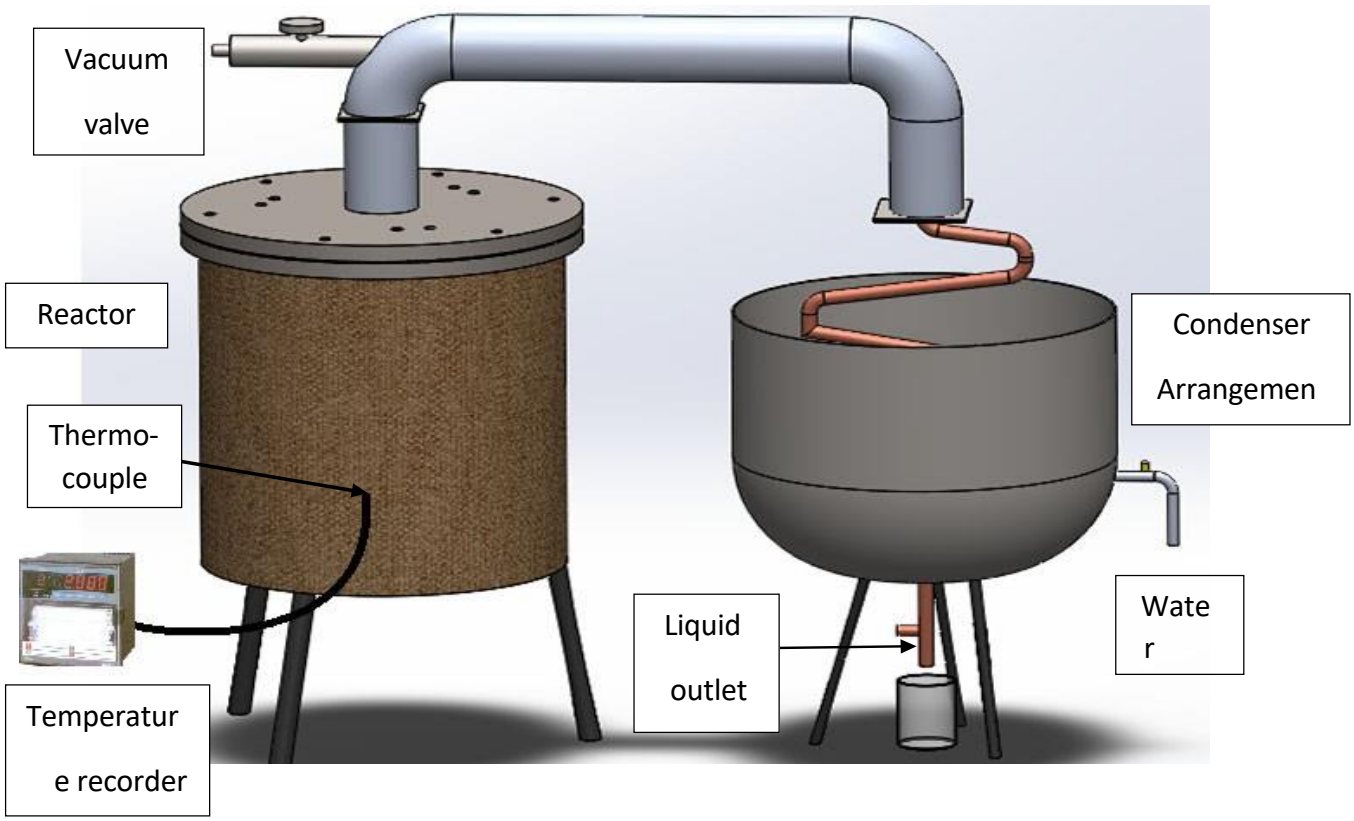
Fig4.3: Heating Arrangement of Process

4.5: Condenser arrangement: A simple gas to water heat exchanger type condenser is provided to condense the volatile gases produced from thermal decomposition. Gas are carried by copper tube and incondensable gases are passed through a bypass pipe under the condenser. Bended copper tube is merged in water which is contained by a container.



Fig 4.4: Condenser arrangement constructed apparatus

4.6: Design of pyrolysis apparatus



4.7: Final Constructed Apparatus



Figure: 4.6: Final Constructed Apparatus

Final collected output



Chapter: V

RESULT AND DISCUSSION

5.1: Experimental data:

The following data are taken during the experiment:

No of Observation	Mass of Feed (gm)	Condenser temperature c (Before)	Condenser temperature c (After)	Starting temperature c	Final temperature c	Time
1	2000gm	15	28	32	380	2(hours)
2	2000gm	16	30	33	385	2(hours)
3	2000gm	15	29	32	382	2(hours)

Table no 1: Experimental data following outputs are obtained from the experiment:

5.2: Relative number of outputs:

No of observation	% of incondensable gas	% of ash	% of liquid (without moisture)
1	51.5	35	4.51
2	46	36.2	5.3
3	45	40.5	5.9

Table no .2: Relative amount of outputs

5.3: Properties of obtained fuel:

Property	Value
Flash point	43.2°C
Pour point	-6°C
Density	0.924 kg/m3
Gross calorific value	21,230.47 kj/kg
Kinetic viscosity at 25°C	9.65*10-6 m2/s
Absolute viscosity at 25°C	8.23*10-3 Ns/m2

Table no 3: Properties of obtained fuel

Chapter: VI

Conclusion

6.1: Conclusion:

In conclusion, the utilization of pyrolysis technology for plastic and rubber waste presents a promising and innovative solution to address the environmental challenges posed by these materials. Pyrolysis, a thermal decomposition process, offers a sustainable approach to managing the growing volumes of plastic and rubber waste, converting them into valuable products while minimizing the environmental impact.

One of the key advantages of plastic and rubber waste pyrolysis is the ability to produce valuable resources such as liquid fuels, gases, and solid char. These products can serve as alternatives to conventional fossil fuels, contributing to a reduction in our dependence on non-renewable resources and mitigating the greenhouse gas emissions associated with their extraction and use. Additionally, the production of high-quality fuels from waste materials aligns with the principles of a circular economy, fostering a more sustainable and resource-efficient approach to waste management.

Furthermore, plastic and rubber waste pyrolysis have the potential to address challenges related to landfill overflow, pollution, and ecosystem degradation. By converting waste into useful products, we can significantly decrease the environmental burden associated with traditional disposal methods and promote a cleaner and healthier environment.

However, it is crucial to acknowledge that the successful implementation of pyrolysis technology requires careful consideration of environmental and safety standards. Efforts should be made to ensure that the process is conducted responsibly, minimizing emissions and potential environmental harm. Additionally, ongoing research and technological advancements are necessary to optimize the efficiency and cost-effectiveness of pyrolysis processes, making them more widely accessible and attractive to industries and communities around the world.

In conclusion, plastic and rubber waste pyrolysis stands as a promising avenue towards a more sustainable and circular approach to waste management. By harnessing the potential of this technology, we can transform the challenges posed by plastic and rubber waste into opportunities for resource recovery, energy production, and environmental conservation. It is imperative that stakeholders, including governments, industries, and communities, collaborate to advance and implement pyrolysis solutions, contributing to a cleaner and more sustainable future.

6.2: Scope of future work:

- Improving the efficiency of plastic and rubber waste pyrolysis processes, optimizing conditions, and developing advanced catalysts.
- Work towards the economic viability of pyrolysis technologies, encouraging industrial-scale implementation and exploring markets for derived products.
- Reducing heat loss, gas leakage, and pressure drop as much as possible.
- Effective processing of plastic waste before pyrolysis may reduce the problem. The best bio-fuel production from plastic waste.
- By improving the plastic & rubber waste section condensation rate can be increased. Which may increase fuel amount and reduce gas loss?

6.3: Discussion:

First objective of this work was designing and constructing a pyrolysis apparatus. By the process of Pyrolysis, plastics can be converted into fuel and in most scenarios three major products are obtained at the end of the process. These products are namely- Pyrolysis Oil, Carbon Black and a Gaseous mixture. All these three are arranged in order of their composition in the product. The properties of pyrolysis oil can be improved by hydrogenation. The pyrolysis oil is a good substitute of conventional fuel and in various test run by Dr. Rao and team it is found that the oil when blended with conventional fuel like petrol & diesel, shows same characteristics as pure fuel dose. It is worth mention to notify that not only pure plastics but also plastics in which additives were used can be treated to form equally good oil . Thermal and catalytic pyrolysis has their own yield aspects for different products. It has been found that can be opted thermal pyrolysis for Liquid products and to catalytic pyrolysis can be preferred for Gaseous products.

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