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Extraction of Fuel from Plastic Waste by Pyrolysis Treatment

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ABSTRACT: *Without the conservation of fossil energy such as crude oil, natural gas, or coal, the current rate of economic expansion is unsustainable. Biomass, hydropower, and wind energy are all viable alternatives to fossil fuels. Plastics have been one of the most widely used materials due to their versatility and low cost. However, recovery and recycling are insufficient, and millions of tonnes of plastic wind up in landfills and the ocean every year. Each year, some 10–20 million tonnes of plastic wind up in the oceans. According to a recent study, approximately 5.25 trillion plastic particles are floating in the world's oceans, weighing a total of 268,940 tonnes. This review article deals with the extraction of oil/diesel from the waste plastics by pyrolysis process termed plastic pyrolyzed oil which is a great alternative to conventional fuel Because the calorific value of plastic is the same as that of hydrocarbon fuel, it provides a good chance to recycle the waste plastic to create the gasoline and liquid oil. Pyrolysis is now a waste-to-energy technological alternative for delivering biofuel to replace fossil fuels. The pyrolysis process has the advantage of being able to handle unsorted and filthy plastic. The pre-treatment of the material is easy. Pyrolysis produces no poisonous or environmentally detrimental emissions. As a result, efforts have been made to overcome this obstacle, the issue of plastic trash, as well as the limitation of fossil fuels by converting plastic waste into fuel.*

KEYWORDS: *Plastic waste, oil, pyrolysis, biofuel, review.*

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I. INTRODUCTION:

The increasing utilization of plastic items caused by the sudden growth human population and living standards had a surprising effect on the environment. Plastics have presently ended up indispensable materials, and the demand is persistently expanding due to their different and appealing applications in families and industries. The utilization of plastic materials is endless and has been growing relentlessly in see of the preferences inferred from their versatility, moderately low taken a toll, and solidness (due to their high chemical soundness and low degradability). A few of the most utilized plastics are polyolefins such as polyethylene and polypropylene, which have an enormous generation and utilization in numerous applications such as electricity and hardware, agriculture-based business, health care, packaging, and so on.[1] Plastic items have become an integral part of our day-to-day life resulting in 8.3 billion metric tons of plastics have been produced in 2017 since the starting of the huge scale production.[2]

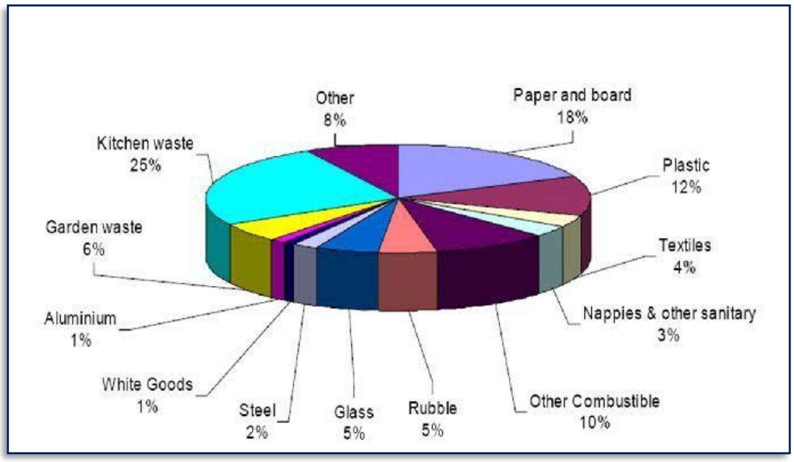

Fig.1 Typical composition of plastic waste sources

Plastic waste can be utilized as a possibly cheap source of chemicals and energy. Due to the discharge of harmful gasses like dioxins, hydrogen chloride, airborne particles, and carbon dioxide, incineration of the polymer has genuine discuss contamination issues. Due to the high took toll and destitute biodegradability, it is additionally undesirable to dispose of by landfill. Over numerous a long time, an exceptional development has been watched in the plastic industry such as within the generation of synthetic polymers spoken to by polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl liquor (PVA), and polyvinyl chloride (PVC). Nearly 60% of plastic solid waste (PSW) is dumped in open space or land occupied around the world, according to estimates. According to a nationwide study conducted in the year 2003, more than 10,000 MT of plastic squander is produced daily in our nation, and as it were 40 wt% of the same is recycled; balance 60 wt% isn't conceivable to arrange off [3].

Sr No.	Year	Consumption in Tonnes
1	1996	61000
2	2000	300000
3	2001	400000
4	2007	8500000

Table 1: Plastics consumption in India [12]

As a result of the increasing use of plastic huge amount of waste is disposed of in the environment plastics is non-Biodegradable waste, they are the cause of many environmental problems the world faces today. The disposal of plastic material is causing a serious effect on wildlife and Marine. Because of inappropriate waste management practices, large masses of plastic items have been released into the environment, and thereby have entered the world's oceans. Ocean serves as a sink for these plastic particles in one estimate 2 lacs microplastics/(km2) of the ocean's surface commonly exist. As per today's statistics, 267 species in the marine environment are affected by plastic entanglement [4].

Main world Area	Plastics consumptions in tonnes	Population in Millions	Kg/Capita	GNI/Capita
Europe W, C, and E	40000	450	90	18000
Eurasia, Russia, and others	4000	285	14	1600
North America	45000	310	145	32000
Latin America	11000	500	22	3500
Middle East, including TR	4000	200	20	2500
Africa, North and South	2500	190	13	2000
Other Africa	500	610	<1	300
China	19000	1285	14	800
India	4000	1025	4	450
Japan	11000	125	90	35000
Other Asia Pacific, rest	13000	1120	11	600
Total world	154000	6100	25	5200

Table 2: Plastics consumption, by major world areas, in kg and GNI dollars per capita

Roughly around 1.15 to 2.41 million tons of plastic enter the sea through streams and accumulates in the sea. The plastic pieces count on earth is even more than the stars in our milky way galaxy. The plastic present solely in the great Pacific Ocean weights equivalent to 3 Statue of Liberty. Consistently marine plastic costs people billions of dollars. The poisonous eating regimen of the life forms move up in the food web influencing people. Socio-economic and ecological consequences. Entanglement, toxicological effects through plastic ingestion, suffocation, Hunger, dispersal, and rafting of animals, the supply of new ecosystems, and the introduction of invasive species.

Present India Situation. The structure and in normal with the Failure to collect plastic waste from the packaging industry and the pipe industry for polyvinyl chloride (PVC) is growing at 16- A year, 18 percent. The demand for plastic goods from household use to industrial uses. It is expanding 22 percent annually at a clip. The creation of polymers has in 2007, reached 8.5 million tonnes. The contrast Production and consumption figures from Tables 2 and 3 display demand and consumption the predictions are right. Over one-fourth of the sum of India's use is that of PVC, which is being phased out. In several nations, out. Packs of poly and other plastic products except for PET in particular, since it has been a priority, Contributing to host problems such as choked sewers in India, Deaths of cattle, and clogged soil. The increasing demand for different types of plastics like polyethylene, polypropylene, polyvinyl, and polystyrene from the year 1995 to 2017 is presented the table 3 below.

Sr. No.	Type of Polymer	1995-96	2001-02	2006-07	2016-17
1	Polyethylene	0.83	0.83	3.27	10.25
2	Polypropylene	0.34	0.88	1.79	9.33
3	Polyvinyl	0.49	0.87	1.29	8.34
4	Polystyrene	0.03	0.14	0.29	6.25

Table 3: Polymers demands in India (million tons).

Following their use, the discarded plastics (plastic waste) Never decay and linger for many years on the landscape. Plastic waste can be recycled, so it's not a permanent solution. A virgin plastic material recycling process It can only be performed 2-3 times because after every recycling, Due to thermal strain, the plastic content decreases which leads to a reduced lifespan. Approximately 70% of Plastic packaging materials are turned into plastic waste. Some technologies have been developed, the harmful effect of plastics on the environment should be reduced. Currently, the most popular technology used for Incineration is the disposal of plastic. It is not, however, the safest alternative as it releases poisonous gases such as chlorinated gases Dioxins, and furans, which pose many environmental concerns. Other advanced technological options are the use of Plastic waste in the building of highways, plastic co-processing Waste in cement kilns as an alternative fuel and raw material Conversion of plastic waste into liquid, and power plants Gas, pyrolysis of plasma, extrusion, and palletization [5,6]. Energy recovery, material recycling, and chemical recycling are all terms used to describe this approach. Among them, one of the prevalent alternative methods is the production of converted fuel and chemicals employing the thermal or catalytic degradation of polymers.

Plastics pyrolysis may provide an alternative means for the disposal of plastic wastes with the recovery of valuable liquid hydrocarbons. Pyrolysis, also known as thermal cracking, is a process in which polymeric materials are warmed to elevated temperatures, causing their macromolecular structures to break into smaller molecules, resulting in a wide range of hydrocarbons. A gas fraction, a liquid fraction containing paraffin, olefins, naphthenes, and aromatics (PONA), and solid residues can be separated from these pyrolytic products. In the presence of commercial fluid cracking catalysts (FCC) or reforming catalysts, more aromatics and naphthenes are preferentially generated in catalytic cracking, increasing the productivity and economics of pyrolysis processes.

1.1 Pyrolysis:

Pyrolysis is a common method for converting plastic waste into energy, which can be in the form of solid, liquid, or gaseous fuels. Pyrolysis is the thermal breakdown of plastic waste in the absence of oxygen at various temperatures (300–900°C) to produce liquid oil. Pyrolysis generates gas, liquid, and solid char, the relative amounts of which depend on the pyrolysis process and the pyrolysis reactor's operating conditions, mainly the heating rate, the working temperature, and the time of residence inside the pyrolysis reactor. Processes such as the processing of charcoal are typical of long residence times and low heating rates, essentially transforming the majority of the carbon contained in the feedstock into elemental carbon. The proportion of liquid generated increases as residence time decreases and the heating rate increases, as there is sufficient heat in the system to boil off any compounds created by the splitting of polymer chains. Very short residence periods and elevated temperatures give conditions very close to those experienced in the process of gasification, thereby creating more gas. Maximizing the production of liquids is beneficial for turning plastic into oil products since this will provide a material that can be quickly transported and processed. With retention times of less than 2 seconds, rapid heating, and temperatures of around 500 ° C, this is accomplished by such 'fast' pyrolysis. Manufacturers of technology involved in the field of converting plastics to oil products have been identified.

In this process of Pyrolysis process of low temperature catalytic thermal decomposition breaks down the plastic feedstock into the following products ➢ 30-90% of the output is mixed low sulfur diesel Alternative fuel, We call it Petro Alternate Fuel (PAF), which can be used in industrial boilers, generators, or can be further refined into diesel and gasoline by the refinery ➢ 5%-42% is solid residue, which can be used as a heating source similar to lean coal ➢ 5%-28% is combustible gas which is recycled back to the furnace as heat [8].
Environment Friendly Process:

1. Wet Scrubber system ensures absolutely no black smoke from the stack.
2. Excess incondensable gas will be recovered for reactor heating, resulting un no gas pollution.
3. Every junction of the reactor is in a good sealing situation with the professional sealing material.

1.2 Process diagram and description:

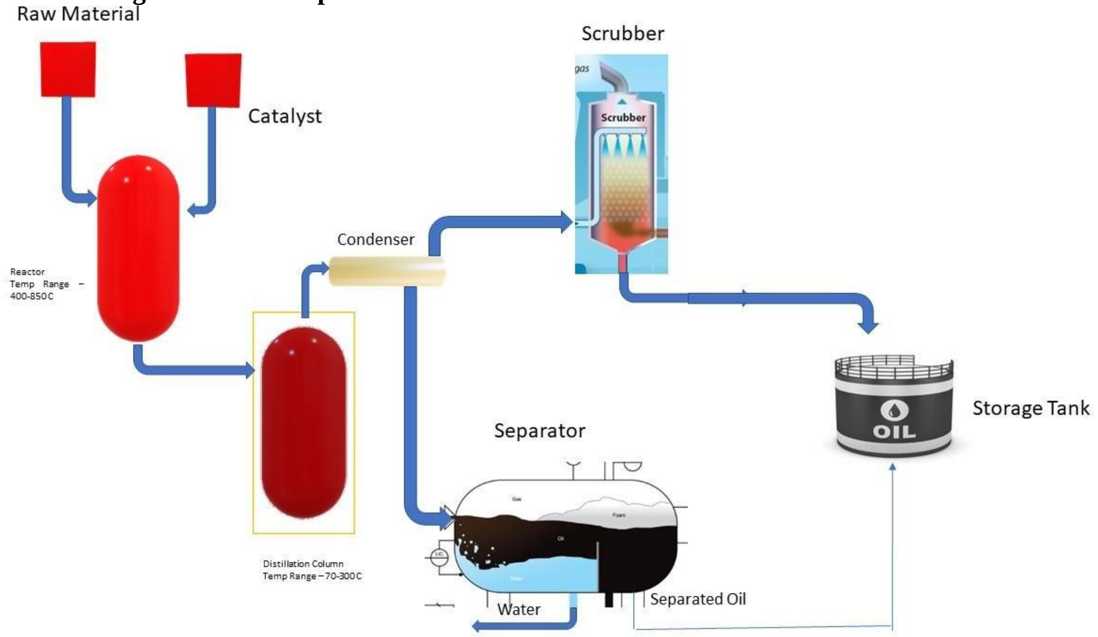

Fig.2: Process Flow Diagram

1.2.1 Reactor

Pyrolysis system is powered by the reactor. It consists of a reaction vessel and a furnace that is insulated on the outside with ceramic wool and cladded with an Aluminium / mild steel sheet. The heating system consists of an oil purification unit, oil pumping unit, and monoblock burners.

The reactor is manually fed raw material and a specific amount of our specialized catalyst. The furnace is heated so that the temperature inside the reactor is in a temperature range where catalytic decomposition takes place depending on various feedstocks. The material is continuously agitated by the rotation of the reactor. The reactor also has the provision for nitrogen purging to create an inert environment to allow the process to happen in the absence of oxygen.[8]

1.2.2 Gas Receiver

The syngas from the catalytic degradation comes out of the reactor and is cleaned using a receiver where the heavier carbon particles and long-chain hydrocarbons condense and flow back to the reactor due to the unique reflux and the lighter fraction is taken to the multi-layer catalytic tower. The syngas velocity also decreases in the cyclone due to which the gas gets more residence time in the catalytic tower and subsequent line.

1.2.3 Catalytic Tower

The syngas is purified using a catalyst in the vapor phase in the catalytic tower.

1.2.4 Anti-Flashback Device

After that, the uncondensed clean gas is pushed through a partially full water tank. The gas moves on to the next component line. The water ensures that the gas that bubbles up does not return to the previous component line.

1.2.5 Mode of Heating

Our equipment has automatic Monobloc burners that are specifically built to burn pyrolysis oil.

1.2.6 Storage Tank

The storage tank holds the Petro Alternate Fuel (PAF).

1.2.7 Scrubber

After being burnt in the furnace, the gas and oil are cleaned by passing them through a wet alkali-packed bed scrubber. To eliminate particle debris from the flue gas, it is cleaned, cooled, and filtered.

1.2.8 Chimney

The flue gas is released into the atmosphere through the chimney once it has cooled.

1.2.9 Flaring System
Without any safety measures, venting exhaust gas (C1 to C4) is harmful. It is transferred first through the safety device, then burned in the burner or Flare system in our procedure.

1.2.10 Control panel
It's utilized to run the whole computer. [8]

1.3 Procedure:

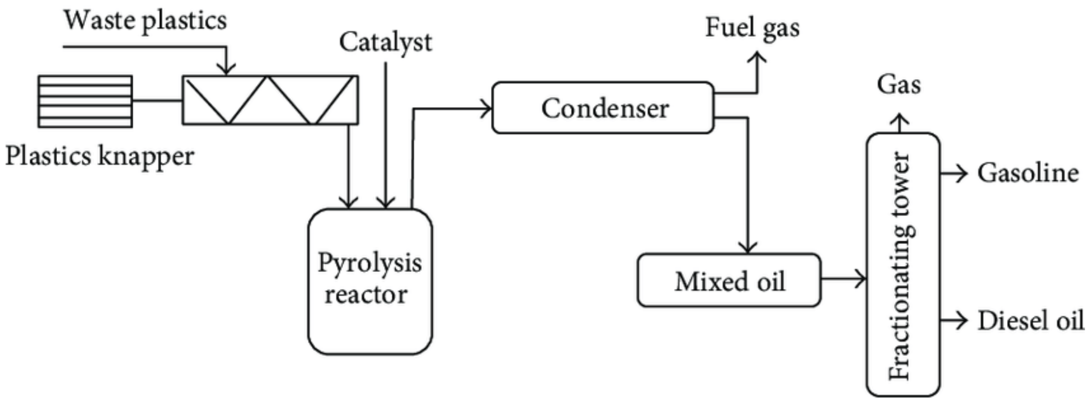

Fig.3: Schematic diagram of converting plastic waste into fuel oil by pyrolysis treatment. [9]

Firstly, plastic waste is collected, then treated to remove all foreign materials before being fed into the reactor, or pyrolysis chamber, the pre-treated plastic raw material is ground to the proper size. The reaction should be able to occur quickly and efficiently, thus the size has to be optimal. Using an auto feeder, input waste plastic pieces into the reactor. The pyrolysis chamber is filled with shredded plastic and an adequate catalyst to promote certain chemical reactions. Heat the reactor. Once the temperature rises to 250°C, oil gas will begin to form gradually. The oil gas is subsequently condensed into liquid oil in the condensing system. This liquid is oil, but it is sent through the refining process. The required oil for use as a fuel is this purified liquid. The gases that cannot be liquefied will be recirculated via the combustion system. It can be reused as fuel to heat the reactor. The temperature will be lowered after the oil production is completed. When the temperature drops below 40°C, the carbon black can be immediately expelled. This can be achieved by using different types of pyrolysis processes, which is explained below in the table 4.[13]

Process	Heating Rate	Residence Time	Temperature	End Products
Slow Carbonization	Very Low	Days	450-600	Charcoal
Slow Pyrolysis	10-100K/min	10-60 min	450-600	Gas, oil, char
Fast Pyrolysis	Upto 1000K/min	0.5-5 s	550-650	Gas, oil, (char)
Flash Pyrolysis	Upto 10000K/min	<1 s	450-900	Gas, oil, (char)

Table 4: End products obtained from different pyrolysis process

1.3.1 Slow pyrolysis:
In this process, biomass is cooked to around 500°C at a slow rate (roughly 0.1-1 oC/s). Compared to liquid and gaseous materials, this low heating rate results in a higher char yield.[10]

1.3.2 Fast Pyrolysis:
Fast pyrolysis uses substantially higher heating rates than traditional pyrolysis (about 10-200°C). The liquid percentage yield is higher in fast pyrolysis because the quick heating rates enables thermolabile biomass components to be converted to a liquid oil before they form unwanted bulk.[10]

1.3.3 Flash Pyrolysis:
Flash pyrolysis is an upgraded variation of fast pyrolysis in which the heating rate is extremely high, >1000°C/sec, with reaction periods ranging from a few seconds to several minutes. Because of the quick heating rate and fast response times, this method requires smaller size particles than the other methods for greater yields.

As explained above and in the table 4, products obtained from these different pyrolysis techniques differs. Right choice of catalyst makes the process more efficient. Using the right catalyst, we can get rid of things like H2S, SOX, and NOX. Condensers: The syngas from the reactor are cooled to liquid Petro Alternate Fuel using shell and tube condensers. Catalysts can be divided into two types: those with only one phase (homogeneous) and those with multiple phases (multiphase) (heterogeneous). Heterogeneous catalysts are the most commonly utilised because the solid catalyst may be easily removed from the liquid product combination. Because heterogeneous catalysts can be reused, they are recommended. The most widely utilised catalysts in the pyrolysis process are zeolite, silica (SiO2), calcium oxide (CaO), and alumina (Al2O3). [14, 15]

II. RESULT AND DISCUSSION:

Properties	PET	HDPE	PVC	LDPE	PP	PS
Calorific value (MJ/kg)	28.2	40.5	21.1	39.5	40.8	43
Viscosity (mm^2/s)	n.a	5.08	6.36	5.56	4.09	1.4d
Density @ 15℃ (g/cm^3)	0.9	0.89	0.84	0.78	0.86	0.85
Pour point (°C)	n.a	−5	n.a	n.a	−9	−67
Flash point (°C)	n.a	48	40	41	30	26.1
Octane number MON (min)	n.a	85.3	n.a	n.a	87.6	n.a
Octane number RON (min)	n.a	95.3	n.a	n.a	97.8	90–98
Diesel index	n.a	31.05	n.a	n.a	34.35	n.a

Table 5: Characteristics of pyrolytic fuels from different types of plastic[11]

The density of fuel has an impact on its usage and spray properties. In a combustion chamber, kinematic viscosity controls the spray pattern and ignition of injected fuel. In general, high viscosity fuels are not recommended for internal combustion engines since they degrade engine efficiency. The fuel's high viscosity makes transporting it to the fuel supply system challenging. In the winter, this situation restricts the usage of high viscosity fuels. Furthermore, using low viscosity fuels can result in major pump and injector spillage. This could result in a reduction in fuel distribution and engine power output. The temperature at which a fluid ceases to flow is known as the pour point. The flashpoint of the fuel is an important factor for preventing fire hazards during storage. When an external flame is applied, the flashpoint of the liquid is defined as the lowest temperature at which the liquid vapor mixed with the air ignites. A high cetane index is useful as an indicator of the liquid product's superior combustion capabilities.

The net product yields will depend on the nature of technology employed, the energy input needed, and the nature of the feedstock, but the outputs are given in Table 6 below are indicated by information from the technology suppliers. It should, therefore, be observed that, for most of these processes, most of the gas and up to 10% of the liquids generated are used to provide the process with heat.

Output	Gross Conversion	Net Conversion
Char	2% to 13% wt	2% to 13% wt
Liquid	77% to 90% wt	67% to 80% wt
Gas	8% to 10% wt	0% wt

Table 6: Reported outputs from pyrolysis of plastic to oil products

The numbers in the above table are displayed as a percentage of the plastic mass fed into the operation. 'Net conversion' involves accounting for the gas and liquid consumption for the energy needed to achieve the operating temperature of the operation.

In Table 7, Observations were made for 100 Kg of plastic waste. The total yield obtained is mentioned after pyrolysis treatment on different types of plastics. Polypropylene and Polystyrene account for the highest oil yield, while Polyethylene terephthalate gives the least oil content but, highest gasoline content. Gasoline yield is minimum in High-Density Polyethylene and Polystyrene. The residue is obtained in the form of Bitumen.

Types of Plastic	Liquid Yield(%)	Gas Yield(%)	Residue (Bitumen)(%)	Total Yield(%)
PET	36.84	54.69	8.49	83-87

HDPE	73.4	26.43	0.17	85-90
PVC	74.2	21.02	4.78	84-88
LDPE	80.05	19.51	0.44	87-91
PP	84.99	0.9	14.11	89-94
PS	87.73	12.23	0.04	88-92

Table 7: Observed yield for different types of plastic (per 100 Kg)

III. CONCLUSION:

Plastics are a huge concern to people and the planet today. Roughly around 1.15 to 2.41 million tons of plastic enter the sea through streams and accumulates in the sea. Despite the fact that humanity has recognised this problem and responded by developing degradable bio-plastics, there has been no clear effort to repair the damage that has already been done. In this respect, the thermal pyrolysis process on plastic waste have been done here and found that it is an efficient, clean, and very effective method of eliminating the debris that we have. Values studied for 100 kg of different types of plastics. Highest value for oil is given by Polypropylene and Polystyrene whereas, for gasoline it is obtained from Polyethylene terephthalate. Polyethylene terephthalate has least yield for biofuel. Total yield for Polyethylene terephthalate, High-Density Polyethylene, Polyvinyl chloride, Low-Density polyethylene, Polypropylene and Polystyrene is measured. We solve two problems by converting plastics to fuel: one is the vast plastic waste, and the other is fuel crises.

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