

REVIEW ON EFFECTIVE PRODUCTION OF FUEL FROM PLASTIC**WASTE USING PYROLYSIS PROCESS****R. Dhanasekaran*, A. Saikumar**, Naveen*** & B. Manideep******Department of Mechanical Engineering, Guru Nanak Institute of Technology,
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Abstract:

In the recent world, there is an abrupt increase in the usage of plastic alongside drastic growth in technology in various activities like household, medical, food packing, automobile etc. It was estimated that only about 20-30% of the whole plastic waste accumulated is being recycled. Recycling of recovered plastic is mainly categorized into four types i.e. re-extrusion, mechanical, chemical and energy recycling. The chemical recycling is observed as the most effective method for converting plastic waste into useful oils. This includes Pyrolysis, a thermal and/or catalytic process. Methods to improve efficiency of this process, types of reactors, optimum temperature and pressure, dehalogenation additives and catalysts are discussed. The aim of this study is to give an overview about the pyrolysis process that effectively produces liquefied fuels from plastic waste. This study concludes that produced liquid fuels can attain higher quality standards effectively with lowered investment.

Key Words: Pyrolysis, Thermal and Catalytic Pyrolysis & Plastic

1. Introduction:

Since few decades it is plastic that has been serving human as a material being noted for its versatility, durability and lightweight. This has resulted in a consequent raise in the demand and utilization of the plastics in day to day life. The non-biodegradable characteristic of the plastics led to an increase in the yield of plastic waste especially in industrialized countries. Plastic waste stands second highest in deposition of the municipal solid waste. Plastic waste consists of mixture of different polymer like polyethylene (PE), polypropylene (PP), high and low density polyethylene (HDPE and LDPE), polystyrene (PS) and polyethylene terephthalate (PET) [24]. The rate of increase of plastic waste has raised up to 4% which accounts on a whole of billion tons globally. Landfills and incineration became an environmental problem due to reason that degradation of plastic material takes long time and thus, high visibility in waste stream. Furthermore, the landfill and incineration methods aren't too effective because they can't recover the organic matter of the plastics which can serve as raw material to petrochemical industries.

The traditional methods like sorting, grinding can recycle only 14-20% of the total generated plastic waste. In pyrolysis, thermal decomposition of plastics produce value added products/fuels at high temperature in inert atmosphere. Unlike incineration, pyrolysis is eco-friendly. It is an effective waste to energy (WTE) convertor [24] [25]. The conventional thermal pyrolysis is setback by its dependance on temperature. The product obtained from the pyrolysis process is categorized into solid liquid and gaseous residues. Liquid yield produced from the thermal pyrolysis is low in quality due to the presence of the impurities like Cl, Br, and Sulphur etc. The thermal pyrolysis of the PE's such as HDPE and LDPE is more difficult due to their cross chained hydrocarbon structure. By using the catalyst such as zeolite, FCC, red mud, HZM-5 one can overcome the problems developed by thermal pyrolysis.

2. Literature Review:

A. Pyrolysis Process: Pyrolysis converts the plastic waste in to the value added products by thermal decomposition at the temperature range of 300-900 °C in the absence of Oxygen, thus being tertiary recycling method [24]. Pyrolysis has the ability to recycle the heterogeneous waste plastic which is difficult to recycle by conventional recycling process. It will create a market accepted value for the produced value added products. Pyrolysis is a thermo-chemical recycling process and can be operated at different temperatures over a range of 300-900 °C, however optimum temperatures for plastic waste are around 450-550 °C. Some authors use different heating rates 5 °C/min [28], 10 °C/min, 15 °C/min [5]. The product obtained from the pyrolysis includes basic petrochemical compounds that can be used as feedstock for petrochemical industries. In this method, polymer degradation takes place through elimination of small molecules and the rate of decomposition depends on the chemical structure of the polymer [2]. Temperature and duration of the reaction affect the yield and composition of the obtained products. One can overcome these limitations by the use of catalyst in the process. Catalytic pyrolysis improves the quality, reduces the halogen content in the obtained yield and also reduces the temperature and retention time of the reaction [28]. Thus the pyrolysis again is divided in to two types like thermal and catalytic pyrolysis.

B. Thermal Pyrolysis: Thermal pyrolysis or non-catalytic pyrolysis is a tertiary recycling process in which the conversion of waste plastic into high value added products/feedstock can be done at a temperature range of 300-900 °C in the presence of nitrogen gas [8]. Thermal pyrolysis is an endothermic process. So it doesn't require any catalyst activity. The thermal cracking requires high temperature and retention time which results in low quality of the liquid oil. It is difficult to control the composition of the obtained yield because reaction is carried at high temperature. Thermal pyrolysis of different plastic waste that has been carried out from last few years are polyolifens [16] [3], polypropylene and polystyrene [23][15], HDPE and LDPE [11] [22]. Thermal pyrolysis of PE, PP, PS, LDPE and PVC at low temperature 350-450 °C produces high molecular weight hydrocarbons [21]. Unlike Polypropylene all other polymer requires high temperature to decomposition in monomers [6]. In case of thermal pyrolysis, the mechanism of the degradation is free radical [2].

C. Catalytic Pyrolysis: In this process the utility of catalyst is done. Catalytic pyrolysis has high potential to produce liquid yield from the waste plastic and reduce the temperature and retention time as compared to the thermal pyrolysis. Several authors studied the catalytic activity of the various catalysts are FCC catalyst [7], HZSM-5 [26], Y-Zeolite and natural Zeolite [20], SiO₂/Al₂O₃

and ZSM-5. By using this method, it can convert the plastic waste into 70-80% high potential liquid oil having HHV of 38-45 MJ/kg, where it can be used as alternative fuel in place of diesel/petrol [6]. The product quality is improved by narrowing their carbon distribution in presence of catalyst [16]. In case of catalytic pyrolysis, the degradation is generally ionic mechanism. From the literature, the use of catalyst helps to reduce the halogens present in the obtained liquid oil [19] [28]. The catalytic activity mainly depends upon the BET surface area, acidity, practical size and pore size [26] [7]. If larger the BET surface area, there is increase in the gaseous yield than liquid yield [20].

3. Factors Effecting the Pyrolysis Process:

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A. Effect of Temperature on Oil Yield Produced by Using Pyrolysis: Temperature is the main parameter which affects the pyrolysis process. The increase in the reaction temperature increases the gaseous yield and decreases the liquid yield in the obtained products. Thermal cracking polymer plastics at low temperature produce high volatile contain in the liquid yield. Temperature is the most studied factor, as it affects the thermal cracking and the secondary reaction of the pyrolysis process. The thermal cracking of different polymer HDPE, LDPE, PP and PE in the ratio 1:1 at 450 °C in a batch reactor was carried [3]. The produced liquid fraction is unstable due to presence of olefins. Naphtha and diesel fractions are hydrogenated over Pd/catalyst at 120 °C. The results found the bromine fraction is reduced the range of 0.02-2 gm in 100 gm of sample, research octane number for naphtha fractions are decreased to values 60.6 to 83.2 and diesel index number for diesel fraction is increased to values of 73.6 to 76.3 after the hydrogenation. The thermolysis of PE, PP and PS at the temperature of 430 °C was carried [4]. The obtained end product has the HHV of 42 MJ/kg and also found that increase in PE and PS, increases the alkenes and aromatic content in the end products. It was concluded that increase in PS and PP, increase the octane number of the end products. The thermal pyrolysis of the PP and PS in the horizontal bath tube at 510 – 520 °C was studied [23]. Author was concluded that the presence of PS in the mixture enhances the degradation of the polypropylene (PP) and also increases the aromatic concentration in the liquid yield. The temperature distribution of the pyrolysis process of PET at the 450 °C was studied [21]. The processed product yield contain the 80 wt % is gases yield very less amount of liquid oil is obtained. It was studied the co-pyrolysis of biomass with the synthetic polymer that is polystyrene [1]. The results found that polystyrene decrease the oxygen content from 9% to 0.7% increases the carbon content from 74% to 89% in the obtained yield and concluded that co-pyrolysis of macroalgae and polystyrene increase the water yield but not the oil yield. The thermal pyrolysis of polypropylene derived from medical syringes in a semi batch reactor at 450-550 °C at the rate of 20°C/min is studied [15]. About 80% of liquid yield is obtained. The liquid oil contains alkanes, alkenes and aromatic rings. The pyrolysis of waste plastic obtained from the landline and phones at 550 °C, N₂ in a semi batch reactor is studied [5]. The processed products contain 54% and 58% of liquid yield, 16.7 and 12.6 wt% of gases, and 28.3 and 32.4 wt% solid residues. The obtained liquid yield context complex mixtures of valuable chemicals are toluene, styrene, ethylbenzene etc. The thermal pyrolysis of HDPE followed by distillation to obtain alternative diesel fuels at 430-440 °C are studied [10]. The resulted liquid oil after distillation contains aliphatic paraffinic hydrocarbons (96%) and very small trace of aliphatic olefin and aromatic compounds with the boiling range to the diesel. The thermal cracking of PE and PP at high temperature (>700 °C) produce olefins mixture but at low temperature produce the high-calorific value gas and condensed hydrocarbon oil and wax. According to the slight change temperature and bed material is affect the yield of the produced liquid [17]. As there is increase in temperature, there is decrease in yield of char and increase in the gas yield.

B. Effect of Catalyst on the Oil Yield Produced Using Pyrolysis: The plastic waste contains different types of impurities like sulphur, metals, chlorine, bromine, which may affect the yield of the produced oils through pyrolysis. The use of catalyst plays an important role to improve the quality of the liquid yield and also reduce the temperature, retention time and halogen compounds as compared to the thermal pyrolysis [18]. The catalytic pyrolysis of plastic waste in a fixed bed reactor with an FCC catalyst was carried [7]. The derived oils and gases from the pyrolysis consist of aliphatic composition with a series of hydrocarbon, which can directly recycle into the petrochemical industries. The catalytic pyrolysis of polyethylene, polystyrene by using various catalysts FCC and natural clinoptiloyie zeolite at the 450-550 °C in a line batch reactor was carried [22]. The results show that catalytic activity of the FCC and NCZ has good ability to produce light hydrocarbons in the obtained liquid yield. The degradation of LDPE by using FCC catalyst in sand fluidized bed reactor at 500 °C was studied [27]. The result shows that the produce liquid oil contain products of iso-butaness and iso-pentane as well as aromatic compounds, finally it was concluded that FCC catalyst has the ability to produce valuable products from the low value matter. The catalytic pyrolysis of the plastic waste by using ZSM-5 and red mud at 400 °C and 500 °C was studied [13]. The results shows that red mud require high temperature than ZSM-5 for thermal degradation and also concluded that ZSM-5 produce high liquid yield has its catalytic activity than red mud. The deactivation of HZSM-5 zeolite during the catalytic pyrolysis of LDPE and HDPE in a batch reactor was [26] studied. The results show that HDPE more deactivates the HZSM-5 zeolite than the LDPE. The impact of stalk additive on the pyrolysis oil, FOECE and also co-pyrolysis of rubber and plastic which produce high oil with high heating value was studied [9]. The results show that the addition of stalk additive to rubber and plastic in the ratio of 4:1 increase the 10.3% of liquid yield than without addition of stalk additive and also increase the hydrocarbons ratio in the oil. The effect of zeolite in upgrading of produced pyrolysis wax oil at 550 °C for 1hr was studied [14]. The results found that HZSM-5 has high potential to convert the pyrolysis wax oil in to 70% of liquid yield which contains aromatic fractions.

The catalytic pyrolysis of low value post-consumer HDPE by using Y-zeolite and MgCo₃ as catalyst at low temperature of 430 to 460°C was studied [11]. The produced plastic oil is distilled into motor gasoline, diesel 1 and diesel 2. By using Y-

Zeolite catalytic run produce (88 to 96 %) of motor and diesel fractions while MgCo₃ yield only diesel fraction. The catalytic pyrolysis of computer casing plastic to reduce the bromine at 450°C in a reflux condenser apparatus was studied [19]. Sodium hydroxide and calcium hydroxide are use as an additive to absorb the bromine content. The result found that by using sodium hydroxide maximum amount of bromine can be reduce (296 mg/l to 27 mg/l). The co pyrolysis of lignocellulosic bio mass with plastic to enhance the carbon content in the yield by using ZSM-5 catalyst in a microwave at 375°C is studied [12]. The result was found that about 38.1% overall increase in carbon content and 90% selectivity towards jet fuel alkane range is obtained. The municipal plastic was of PP, PE and PS containing BRF (brominated flame retardants) which increase the bromine content in the products obtained from the pyrolysis. So author added hydrotalcite to the sample and conducted the catalytic pyrolysis at 400°C at the rate of 5°C/min. The result was found that hydrotalcite not only increase the oil but also removes the bromine content from both oil and generated gas.

4. Conclusion:

At present there are various recovery and recycling technologies for the plastic waste. Among all of these tertiary or chemical or pyrolysis is the most effective method by which it can convert the waste plastic into the high value added products. As per the statistics, plastic is derived from the petrochemical products, now there is shortage of the primary fuels like petrol and diesel. So it has to find an alternative method or fuel which can be replaced in the place of those primary fuels. By the pyrolysis of the waste plastic, one can recover the organic matter present in the plastic which has high potential to be used as fuels and one can reduce consumption of the primary fuels. Pyrolysis is carried out by two methods. First, thermal pyrolysis has the high potential to convert the waste plastic into the high value added oils/fuels. There are some limitations by the conventional thermal pyrolysis like high temperature, low quality of produced oil and high energy input. These can be compensated by the use of catalyst in the pyrolysis process. The catalyst improves the quality, reduces the halogen content in the produced oil and also reduces the temperature and retention time of the reaction. The obtained product has three fractions: liquid, gas and char or solid residues with high heating value. The obtained char can be used as energy input for the process and also as the absorber in the water cleaning process. Finally, it is concluded that proper selection of catalyst and optimum temperature helps to produce the desired quality of the products with high heating value. Furthermore, research has to require improving the process efficiency and minimization of the cost.

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