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Review

A review on pyrolysis of plastic wastes

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ABSTRACT

The global plastic production increased over years due to the vast applications of plastics in many sectors. The continuous demand of plastics caused the plastic wastes accumulation in the landfill consumed a lot of spaces that contributed to the environmental problem. The rising in plastics demand led to the depletion of petroleum as part of non-renewable fossil fuel since plastics were the petroleum-based material. Some alternatives that have been developed to manage plastic wastes were recycling and energy recovery method. However, there were some drawbacks of the recycling method as it required high labor cost for the separation process and caused water contamination that reduced the process sustainability. Due to these drawbacks, the researchers have diverted their attentions to the energy recovery method to compensate the high energy demand. Through extensive research and technology development, the plastic waste conversion to energy was developed. As petroleum was the main source of plastic manufacturing, the recovery of plastic to liquid oil through pyrolysis process had a great potential since the oil produced had high calorific value comparable with the commercial fuel. This paper reviewed the pyrolysis process for each type of plastics and the main process parameters that influenced the final end product such as oil, gaseous and char. The key parameters that were reviewed in this paper included temperatures, type of reactors, residence time, pressure, catalysts, type of fluidizing gas and its flow rate. In addition, several viewpoints to optimize the liquid oil production for each plastic were also discussed in this paper.

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1. Introduction

Plastic plays a vital role in enhancing the standard lives of human being for more than 50 years. It is a key of innovation of many products in various sectors such as construction, healthcare, electronic, automotive, packaging and others. The demand of commodity plastics has been increased due to the rapid growth of the world population. The global production of plastic has reached about 299 million tons in 2013 and has increased by 4% over 2012 [1]. The continuous rising of plastic demand led to the growing in waste accumulation every year. It was reported that 33 million tons of plastic waste are generated in the US based on 2013 statistic [2]. As in Europe, 25 million tons of plastic ended up in waste stream during the year of 2012 [1]. Based on the statistic established in Europe, about 38% of the plastic waste still went to the landfill, 26% were recycled while 36% were utilized for energy recovery [1]. This shows that the percentage of plastic waste ended up in the landfill still very high that it occupied a huge space. Plastics may take up to billions of years to degrade naturally. They degrade gradually since the molecular bonds containing hydrogen, carbon and few other elements such as nitrogen, chlorine and others that make plastic very durable. The continuous disposal of plastic in the landfill would definitely cause serious environmental problem.

In order to reduce plastic disposal to the landfill, recycling method is considered as another alternative to manage plastic waste. Back to the statistic mentioned above, the percentage of recycling still at the lowest. Recycling plastic has proven difficult and it can be costly because of the constraints on water contamination and inadequate separation prior to recycle that is labor intensive [3]. Separation is needed since plastics are made of different resin compound, transparency and color. Normally, pigmented or dyed plastics have lower market value. Clearly transparent plastics are often desirable by the manufacturers since they can be dyed to transform into new products, thus have greater flexibility [4]. With the stringent requirement to get high value product, recycling plastic becomes quite challenging nowadays.

Although plastic recycling able to reduce some amount of plastic waste, the more reliable and sustainable method has been established. Since high demand of plastics have been received each year, the reduction of fossil fuel such as coal, gas and especially petroleum that made up plastic itself has gained great interest of many researchers to discover and develop potential energy resources due to the rising in energy demand. Some of the new energy resources that have been explored include solar energy, wind power, geothermal and hydropower technology. Recently, the energy conversion from waste has been an intelligent way to fully utilize the waste to meet the increased energy demand. The conversion of plastics to valuable energy is possible as they are derived from petrochemical source, essentially having high calorific value. Hence, pyrolysis is one of the routes to waste minimization that has been gaining interest recently.

Pyrolysis is the process of thermally degrading long chain polymer molecules into smaller, less complex molecules through heat and pressure. The process requires intense heat with shorter duration and in absence of oxygen. The three major products that are produced during pyrolysis are oil, gas and char which are valuable for industries especially production and refineries. Pyrolysis was chosen by many researchers since the process able to produce high amount of liquid oil up to 80 wt% at moderate temperature around 500 °C [5]. In addition, pyrolysis is also very flexible since the process parameters can be manipulated to optimize the product yield based on preferences. The liquid oil produced can be used in multiple applications such as furnaces, boilers, turbines and diesel engines without the needs of upgrading or treatment [6]. Unlike recycling, pyrolysis does not cause water contamination and is considered as green technology when even the pyrolysis by-product which is gaseous has substantial calorific value that it can be reused to compensate the overall energy requirement of the pyrolysis plant [7]. The process handling is also much easier and flexible than the common recycling method since it does not need an intense sorting process, thus less labor intensive.

Many research papers have been published regarding the potential of various types of plastics in pyrolysis processes for liquid production. It should be noted that the product yield and quality heavily depends on the set up parameters. Therefore, this review focused on different type of plastic pyrolysis that has been explored together with the main affecting parameters in plastic pyrolysis process that need an attention in order to maximize liquid oil production and enhance the oil quality. The main parameters include temperature, type of reactors, residence time, pressure, different catalysts usage and type of fluidizing gas with its flow rate. Additionally, some relevant discussion regarding the optimization of liquid oil yield was also presented in this paper.

2. Pyrolysis of plastics

Fundamentally, different types of plastics have different compositions that normally reported in terms of their proximate analysis. Proximate analysis can be defined as a technique to measure the chemical properties of the plastic compound based on four particular elements which are moisture content, fixed carbon, volatile matter and ash content [8]. Volatile matter and ash content are the major factors that influence the liquid oil yield in pyrolysis process. High volatile matter favored the liquid oil production while high ash content decreased the amount of liquid oil, consequently increased the gaseous yield and char formation [7]. Table 1 summarized the proximate analysis of different plastics. Based on Table 1, it was observed that the volatile matter for all plastics is