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Pyrolysis Tool Prototype for Conversion of Plastic Bag Waste to Liquid Fuel

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Abstract:
The community's need for fossil fuels (BBM) derived from fossils is increasingly increasing, causing increasingly depletion of oil and gas reserves. According to Dudley (2015), world oil reserves at the end of 2014 amounted to 1700.1 billion barrels, whereas in Indonesia only reserves had proven oil reserves of 3.7 billion barrels and the amount was only 0.2% of the total oil reserves in world. On the other hand, plastic waste material is an appropriate alternative as a starting material for hydrocarbon sources and can be a potential source of hydrocarbons with a hydrogen / carbon ratio that is quite high compared to coal (Antal et al., 2000). The type of plastic waste that is often a problem in various cities in Indonesia is the type of plastic bags (LDPE), this is due to the waste plastic bags sold unsold for sale on the market. From a variety of existing literature, research is still on a laboratory scale so further studies and testing are needed to a larger scale in the form of a prototype. This research also aims to convert plastic bag waste (LDPE) into liquid fuel and perform various analyzes. The reactor temperature is maintained at (140, 150, 160, 170, 180 oC) and the processing time is 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 190 minutes. Pyrolysis Reactor Prototype Unit can be used to convert plastic bag waste (Low Density Polyethylene) (LDPE) into liquid fuel with a yield of 43.77% or 6.9 kg of the total mass of plastic raw material waste of 15.47 kg and processing time the optimal is 180 minutes with a heating value of 19750 Btu / lb.

Keywords: Ldpe, Plastic, Bbc, Pyrolysis, Liquid Fuel

1. INTRODUCTION

The community's need for fossil fuels (BBM) derived from fossils is increasingly increasing, causing increasingly depletion of oil and gas reserves. According to Dudley (2015), world oil reserves at the end of 2014 amounted to 1700.1 billion barrels, whereas in Indonesia only reserves had proven oil reserves of 3.7 billion barrels and the amount was only 0.2% of the total oil reserves in world. Total oil production is 852 thousand barrels / day with consumption of 1,641 million barrels / day. From the data above, it can be seen that there is an imbalance between production and consumption, so that the availability of fuel in Indonesia will enter a critical stage.

The issue of the depletion of world oil reserves (Marcilly, 2003), the more demanding a tactic and strategy for the main source of hydrocarbons in a cost-efficient and efficient manner. Considering that the formation process in terms of geological time frame requires thousands of years, the fossil energy source is referred to as a nonrenewable resource.

On the other hand, plastic waste material is an appropriate alternative as a starting material for hydrocarbon sources and can be a potential source of hydrocarbons with a hydrogen / carbon ratio that is quite high compared to coal (Antal et al., 2000). The type of plastic waste that is often a problem in various cities in Indonesia is the type of plastic bags (LDPE), this is due to the waste plastic bags sold

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unsold for sale on the market, another case with the type of plastic waste such as drink bottles, household plastic waste equipment etc. which can still be sold at a price of 2000 to 3000 per kilogram. So that waste plastic bags Plastic bags really have become hazardous and difficult to manage and spread in the city body so that and become a very urgent problem to be overcome.

KLHK notes, the use of plastic bags classified as (LDPE) in Indonesia, more than 1 million pieces per minute. Every year, the production of plastic bags consumes around 8% of world oil production or around 12 million barrels of petroleum fuel.

The reliability of plastic bags belonging to the type (Low Density Polyethylene) (LDPE) to be used as fuel is not only limited to the amount that can be consumed continuously as a raw material, but the component formula inside is very potential. The main constituent components consist of polyethylene which is free from other chemical compositions such as tereptalat in the type of PET plastic (polyethylene terephthalate, PVC (Polyvinyl Chloride) and other types so that during the conversion process into fuel does not contain much residue which can reduce the percent yield and become a scale factor or impurity material in the piping system used Other reliability of melting point plastic bag waste is relatively much lower than other types of plastic.The plastic melting point of LDPE type is in the range of 115oC, while for HDPE in the range of 135 oC.Low melting temperature from plastic waste will provide benefits in terms of the process because the heating temperature in the reactor will be lower than other plastic waste raw material.

LDPE plastic waste conversion research, especially plastic bags, has been carried out and has obtained various operating conditions and yield values produced. Recorded since 2012 Moinuddin Sarker of the United States Department of Research and Development, carried out the degradation process in the Pyrolysis Reactor at a temperature of 250 oC and the resulting yield reached 40%.

In 2014, P. Premkumar from Annamalainagar University of India converted from LDPE plastic waste in a pyrolysis reactor at 250 oC to obtain a liquid fuel formation of 35%.

Stepping on in 2017, S.L. Wong from Universitas Teknologi Malaysia carried out plastic pyrolysis of LDPE type plastic bags and obtained optimal degradation temperatures at 252.3 oC with a yield of 38%.

The three studies that have been carried out to convert plastic bag waste into liquid fuel all refer to the pyrolysis process. Pyrolysis or evolutionization is the process of fractionating material by temperature. When components are thermally unstable, and volatile matters in plastic waste will break and evaporate along with other components. The vaporized liquid product contains tar and hydrocarbons. The speed of the decomposition reaction in pyrolysis is based on changes in mass or mass fraction of time. Pyrolysis products will be strongly influenced by temperature and time and the temperature attainment in the pyrolysis reactor will be greatly influenced by the temperature regulation in the reactor (Rodiansono et al 2007).

If examined further, various studies that have been carried out, have obtained a variety of good operating conditions with the achievement of the percentage of results that are above 40%. However, from a variety of existing literature, research is still on a laboratory scale so that further assessment and testing is needed to a larger scale in the form of a prototype.

Based on the description above, the scope of this research intends to develop the process of converting plastic bag waste into liquid fuel which is carried out on a prototype scale equipment unit by using various operating conditions of the results of previous studies.

2. LITERATURE STUDY

1. Plastic

The development of plastic began with the discovery of the first plastic derived from natural polymers, namely celluloid in 1869 by American investor John W, Hyatt and formed in 1872. The first plastic was composed of cellulose nitrate, camphor, and alcohol.

Plastic became a modern industry after the production of Bakelite by American Chemist L. H Baakeland in 1909. Bakelite is composed of phenol and formaldehyde polymers. During its development, plastic is used in various forms and uses, such as cutlery, food packaging, optical lenses, building structures, furniture, fiberglass, and others (Azizah, 2009).

Plastic is a type of macromolecule formed by the polymerization process. Polymerization is the process of combining several simple molecules (monomers) through a chemical process into large molecules (macromolecules or polymers). Plastic is a polymer compound whose main constituent elements are carbon and hydrogen. Plastics also contain additives, which are substances used to improve the properties of plastics. Additives in the form of substances with low molecular weight that can function as dyes, antioxidants, absorbent of ultraviolet light, non-sticky and so on. The structure of monomers and plastic polymers can be seen in Figure 1.

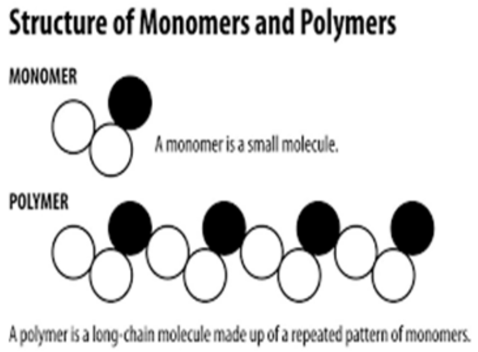

Figure 1. Structure of monomers and polymers (Source: wikipedia, accessed 12 July 2018)

To make plastic, one of the materials used is naphta, which is a material produced from refining petroleum and natural gas. Plastic compositions and materials are polymers and other additives. As an illustration, to make 1 kg of plastic requires 1.75 kg of petroleum, to meet the needs of raw materials and process energy requirements. Polymers are made by assembling monomer chains which can be done by thermosetting and thermoplastic methods. In the thermosetting method, the liquid monomer is poured into a mold and allowed to cool. Liquid monomers have a permanent shape so that the resulting product is durable.

With the thermoplastic approach, the liquid monomer is heated and slowly formed as needed. After that, the product is then cooled down to become the desired item. While plastic is generally considered a cheap product, plastic can also be processed into something of high value. Plastic can be further processed so that it has the characteristics of heat and cold resistance. Car or airplane components are examples of high-quality plastic.

The basic structure of plastic chemistry is covalent bonding. Plastic is a hydrocarbon molecule. Molecules from plastic are called macro molecules because of their enormous size in terms of the number of carbon atoms. Plastic has advantages compared to other materials, namely:

1. Not water impermeable
2. Easy to shape and print
3. Lightweight
4. Not easily broken and flexible / flexible
5. Heat and electricity insulator
6. Easily colored.

These advantages are causing an increase in the use of plastic from time to time.

2. Thermal Properties of Plastics

Plastics are made by conducting a polymerization reaction, which is the reaction of combining small molecules (monomers) that form larger molecules. There are two types of polymerization reactions, namely addition polymerization and condensation polymerization. Addition polymerization occurs in monomers that have unsaturated bonds (double bonds) by opening the double bonds and producing polymer compounds with saturated bonds. Whereas polymerization occurs by releasing molecules in functional groups to form larger molecules. Addition polymerization can be seen in Figure 2 and Condensation polymerization can be seen in Figure 3.

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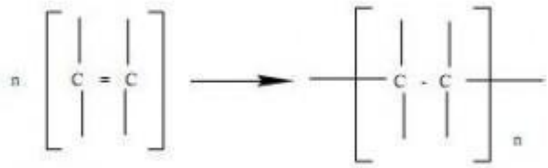

Figure 2. Addition polymerization reactions
(source: rumuskimia.net, accessed 20 July 2018)

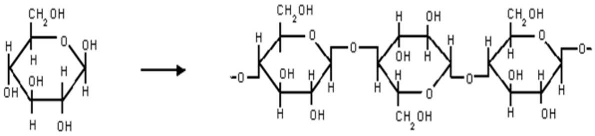

Figure 3. Condensation polymerization reaction (source: rumuskimia.net, accessed 21 July 2018)

Knowledge of the thermal properties of various types of plastics is very important in the process of pyrolysis of plastic waste. Important thermal properties are melting point (Tm), transition temperature (Tg) and decomposition temperature. Transition temperature is the temperature at which the plastic undergoes a structural collapse so that changes from rigid conditions become more flexible. The comparison of the heating value contained in plastic with other sources of heat can be seen in table 2.1 below:

Material	Nilai Kalor (MJ/kg)
Polyethylene	46,3
Polypropylene	46,4
Polyvinyl chloride	18,0
Polystyrene	41,4
Coal	24,3
Petrol	44,0
Diesel	43,0
Heavy fuel oil	41,1
Light fuel oil	41.9
LPG	46,1
Kerosene	43,4

Sumber: Das dan Pande, 2007

Table 2.1 Comparison of plastic heating value with other materials

3. Types of Plastics and their Characteristics

Based on the source, plastics are grouped into 2 types namely natural polymers and synthetic polymers. Natural polymers are polymers whose raw materials are obtained naturally from nature. Examples are bark, animal skin, natural rubber and hair.

While synthetic polymers are synthetic polymers that are synthesized from industry. Synthetic polymers are divided into three namely:
1.Not naturally present in nature: for example nylon, polyester, polypropylene, polystyrene.
2. Available in nature but made synthetically. An example is natural rubber.
3. Modified natural polymer. An example is celluloid, cellophane (the basic ingredient of cellulose but has been radically modified so that it loses its original chemical and physical properties.

Based on its physical properties, plastics can be grouped into two types, namely thermoplastic and thermosetting. Thermoplastic is a plastic which, when heated to a certain temperature, will melt and can be reshaped to the desired shape. Examples are polyetylene (PE), Polystyrene (PS), ABS, and Polycarbonate (PC). Whereas thermosetting is plastic which, if it has been made in solid form, cannot be melted back by heating it. Reheating will cause damage to the molecules. Examples are epoxy resins, bakelites, melamine resins, urea-formaldehyde. Based on the second nature of the plastic, Thermoplastic is a type that allows for recycling. The type of plastic that can be recycled is given a code number to make it easier to identify and use. Types of plastics, codes and their use as shown in Figure 4 and Table 2.

Figure 4. Plastic code number
(Source: Untoro, 2014)

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Table 2. Types of plastics, codes and function

No. Kode	Jenis Plastik	Penggunaan
1.	PET (*polyethylene terephthalate*)	botol kemasan air mineral, botol minyak goreng, jus, botol sambal, botol obat, dan botol kosmetik
2.	HDPE (*High-density Polyethylene*)	botol obat, botol susu cair, jerigen pelumas, dan botol kosmetik
3.	PVC (*Polyvinyl Chloride*)	pipa selang air, pipa bangunan, mainan, taplak meja dari plastik, botol shampo, dan botol sambal.
4.	LDPE (*Low-density Polyethylene*)	kantong kresek, tutup plastik, plastik pembungkus daging beku, dan berbagai macam plastik tipis lainnya.
5.	PP (*Polypropylene atau Polypropene*)	cup plastik, tutup botol dari plastik, mainan anak, dan margarine.
6.	PS (*Polystyrene*)	kotak CD, sendok dan garpu plastik, gelas plastik, atau tempat makanan dari styrofoam, dan tempat makan plastik transparan
7.	Other (O), jenis plastik lainnya selain dari no.1 hingga 6	botol susu bayi, plastik kemasan, gallon air minum, suku cadang mobil, alat-alat rumah tangga, komputer, alat-alat elektronik, sikat gigi, dan mainan lego

(Sumber: Untoro, 2014)

a. (Polyethylene terephthalate)

PETE or PET (polyethylene terephthalate) is commonly used for clear / transparent / transparent plastic bottles such as mineral water bottles, juice bottles, and almost all other beverage bottles. This PET / PETE type bottle is recommended for single use only. Why? If it is used too often, especially if it is used to store warm water, especially heat, it will cause the polymer coating on the bottle to melt and remove carcinogenic substances (can cause cancer) in the long run. So for those who use bottles of mineral water to be cooled in the refrigerator, you should replace the bottles into bottles made of glass.

b.HDPE (High density polyethylene)

HDPE (high density polyethylene) has the properties of materials that are stronger, harder, opaque and more resistant to high temperatures. Code 2 is commonly used for milk bottles that are white milk, Tupperware, gallons of drinking water and others. HDPE is a plastic material that is safe to use because of its ability to prevent chemical reactions between HDPE-based plastic packaging and the food / drink it packs. Even so, code 2 is also recommended for single use only. Why? because the release of antimony trioxide compounds continues to increase over time.

c.PVC (Polyvinyl chloride)

PVC (polyvinyl chloride) is the most difficult plastic to recycle. This plastic can be found in plastic wrap (cling wrap), and bottles-

d.LDPE (Low density polyethylene)

LDPE (low density polyethylene) is commonly used for food containers, plastic packaging, and soft bottles. Items with code 4 can be recycled and are good for items that require flexibility but are strong. Items with code 4 arguably cannot be destroyed but are still good for food containers because it is difficult to react chemically with foods that are packaged with this material.

e.PP (Polypropylene)

PP (polypropylene) is the best choice for plastic materials, especially for those related to food and drinks such as food storage, drinking bottles and most importantly drinking bottles for babies. Its characteristics are transparent, not clear or cloudy, and quite shiny. Polypropylene is stronger and lighter with low vapor penetration, good resistance to fat, stable to high temperatures.

f.PS (Polystyrene)

PS (polystyrene) is commonly used as a material for eating styrofoam, disposable drinking places, etc. Ingredients Polystyrene can leak styrine ingredients into food when the food is in contact. Styrine is dangerous for brain health, disrupting the hormone estrogen in women which results in reproductive problems, and nervous system. In addition to food containers, styrine can also be obtained from cigarette smoke, vehicle fumes and building construction materials. This material must be avoided and many states in America have banned the use of Styrofoam-made food containers including China.

g.OTHER

For this 7 Other plastic type there are 4 types, namely SAN (styrene acrylonitrile), ABS (acrylonitrile butadiene styrene), PC (polycarbonate) and Nylon.Other (usually polycarbonate) can be found at food and beverage places such as sports drinking bottles, spare parts cars, household appliances, computers, electronics, and plastic packaging. Polycarbonate can release its main ingredient, Bisphenol-A, into foods and drinks that have the potential to damage the hormone system.

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Avoid Polycarbonate plastic materials. The following is a table of types of plastic and their use:

4. Chemical Structure of Low-density Polyethylene (LDPE)

Low-density polyethylene (LDPE) is a thermoplastic made from ethylene monomers. Low-density polyethylene (LDPE) is the first class of polyethylene, produced in 1933 by Imperial Chemical Industries (ICI) using a high-pressure process with free radical polymerization. Despite competition from more modern polymers, LDPE continues to be an important plastic class. In 2013, LDPE markets around the world reached a volume of around US $ 33 billion. LDPE is a plastic that is easily formed when hot, which is made from petroleum. the molecular formula (-CH2- CH2-) n. LDPE has a density between 0.92-0.94 g / mL and has a melting point at a temperature of 115 oC. The molecular formula is (C2H4) n as in Figure 5 :

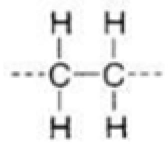

Figure 5. Molecular Structure of LDPE
(source: wikipedia, accessed on July 17, 2018)

Produced through free radical polymerization, LDPE has long and short chain branches of various forms of PE, resulting in a lower density. Branching makes the molecular chain not tightly packed in its crystalline form, so that LDPE has less tensile strength but has greater tenacity. This extraordinary "formatting ability" makes LDPE very useful

LDPE is a resin that is hard, strong and does not react to other chemicals, is the highest quality plastic. Usually used for food containers, plastic packaging, soft bottles, plastic bags, etc. Examples of LDPE plastic materials can be seen in Figure 5.

Figure 5. LDPE material
(source: ljplastindo.com, accessed on July 17, 2018)

3. METHODOLOGY

1. Simple Static Treatment and Analysis

In this study, the variables to be taken consist of fixed and non-permanent variables. This research was conducted with data obtained from measurement results compiled in tabular form to be used as a study material in determining the performance of plastic bag waste prototype conversion units in terms of characteristics (heat value, density, viscosity, flash point) and yield produced by the reactor pyrolysis unit. so it can be used as fuel for motor fuel.

a) Fixed variables:

- Mass Plastic bags: 15,464 kg
- Reactor volume: 0.371 m3
- Coconut shell mass: 52 kg / minute burning

b) Changed Variable:

- Processing Time: 15, 30, 45, 60, 75, 90, 105, -120, 135, 150, 165, 180, 190 minutes
(0 minutes is calculated after the reactor temperature reach design temperature)
-Process Temperature: (140, 150, 160, 170,180 ^{o}C) . (temperature regulation is done with regulate fuel consumption and process pressure in the reactor)

2. Process of Converting Waste Plastic Bags (LDPE) Into Liquid Fuels

Block diagrams and process flow diagrams of Prototype Unit Conversion of Plastic Waste Bags

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used can be seen in Figures 6. and 7. below :

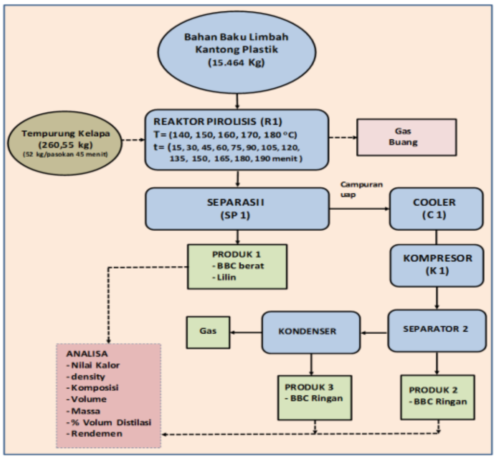

Figure 6. Block diagram of the Pyrolysis Process

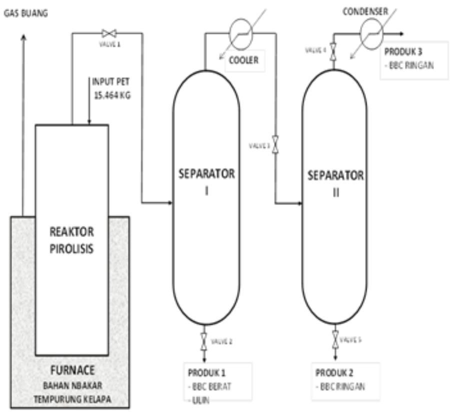

Figure 7. Simple Block Diagram ToolPlastic Bag Conversion

4. RESULT AND DISCUSSION

1. The Effect of Process Time and Temperature on BBC Percentage

The time and temperature of the degradation process will affect the yield of liquid fuels (BBC 1) and (BBC 2) produced. The graph that is used to influence the time and temperature of the deghradation process on the percent of BBC yield produced can be seen in Figures 8 to 10. Figure 8. for liquid fuels (BBC 1), Figure 9 for BBC 2 and Figure 10 for total liquid fuel yields or the total sum of BBC 1 and BBC 2. From graph 4.1 it can be seen that the effect of processing time in this study gives a significant condition in the processing time of 105 to 165 minutes for the increase in yield of BBC 1 (separator product 1) and the effect of temperature has a very good effect at temperatures of 170 to 180 oC which gives a maximum increase in yield of 4.7%. While from Graph 4.2 it can be seen that the influence of processing time in this study provides a significant condition at the time the process starts at 90 minutes to 165 minutes for the increase in yield of BBC 2 (separator product 2) and the effect of temperature gives a very good effect at temperatures of 170 to 180 oC which gives a maximum percent increase in yield at 6.58%.

For Figure 8 as a percent increase in total yield gives a picture that is not too much different from the pattern that occurs in Figure 4.2. This is because the increase in percent yield is dominated by BBC 2 components. BBC total. While the optimal temperature occurs at a temperature of 170 oC, this is because at 180 ^{o}C of the three graphs it appears that the flow graph that occurs is very coincide in other words percent yield does not give much increase in yield at a temperature of 180 ^{o}C and if forced then the process will waste energy.

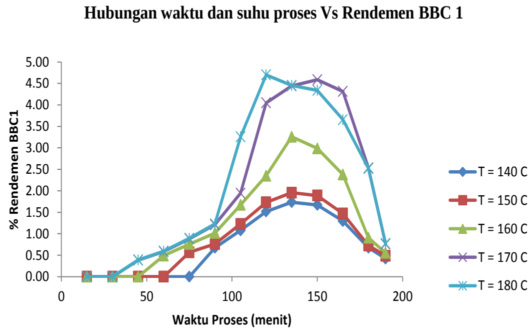

Figure 8. Time and Temperature Graph of the Process Against BBC Yield 1

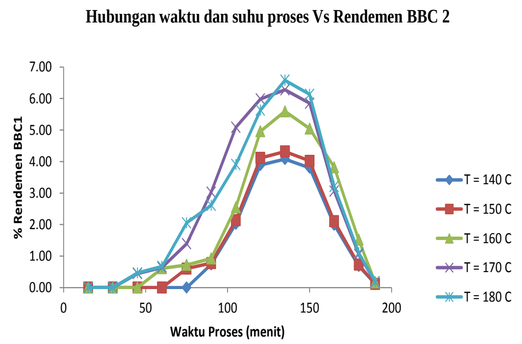

Figure 9 Time and Temperature Graph of the Process Against BBC Yield 1

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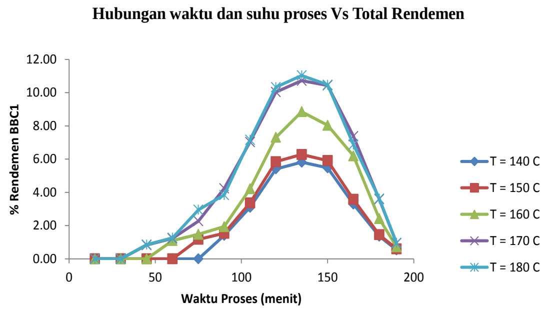

Figure 10. Time and Temperature Graph of the Process Against BBC Yield 1

The effect of processing time has a very significant effect on the percent of liquid fuel yield, this is because the length of time will provide sufficient time for the cracking of polyethylene polyethylene waste components into liquid hydrocarbon components. Broadly speaking, with the available time, the utilization of heat energy provided can be used maximally during the process of breaking the polyethylene chain (LDPE). Time will also affect the product to be produced, the longer the pyrolysis process takes place the product it produces (solid residues, tar, and gas) increases. The increase is up to infinite time (□), which is the time required until the yield of solid residue, tar and gas reaches a constant. When the processing time exceeds the optimal time, carbon will be oxidized by oxygen (burning), becoming carbon dioxide and ash. For this reason, the pyrolysis process in determining the optimal time is very important. Taking the assumption that the decomposition reaction takes place progressively or uniformly on all particles, the equation of the reaction rate is expressed in mass fractions per unit time. Percentage of the total liquid fuel yield at an optimal time of 180 minutes reaches 43.77% and the maximum at 190 minutes.

Temperature greatly affects the amount or yield of the product produced because it is in accordance with the Arhenius equation, the higher the temperature value of the thermal decomposition constant the greater the consequence the pyrolysis rate increases and conversion increases. Based on the Arrhenius theorem the relation of the constants of the reaction equation to absolute temperature, is:

k = k0. e- (E / RT) (3)

with,

k = constant rate of decomposition reaction thermal

ko = collision factor (frequency factor)

E = Activation energy (cal / gr.mol)

T = absolute temperature (0K)

R = gas constant (1.987 cal / gr.mol0K)

Temperature can be said as heat assistance in the pyrolysis process or thermal cracking process (thermal cracking) in the form of breaking long hydrocarbon chains into hydrocarbons with smaller chains. In the pyrolysis reaction of polyethylene terephthalate at the beginning of the process there will be a break of the CC and CO chains in the hydrocarbon chain because these two bonds have very low bond energies of only about 350 kJ / mol compared to other atomic bonds such as C = C which reaches 837 kJ / mol his. So that the breakdown of polyethylene into shorter chains will occur at temperatures that are not too high. The process of pyrolysis of plastic bags (Low Density Polyethylene) (LDPE) in this study took place optimally at a temperature of 170 oC with a total percent yield of BBC 1 and BBC 2 of 57.74%.

5. CONCLUSIONS AND SUGGESTIONS

1. Conclusions

From the research that has been done as well as quantitative and qualitative analysis of the results of the study, it can be concluded that:

1. Pyrolysis Reactor Prototype Unit can be used to convert plastic bag waste (Low Density Polyethylene) (LDPE) into liquid fuel with a yield of 43.77% or 6.9 kg of the total mass of plastic waste raw material as much as 15.47 kg.
2. The optimal processing time is 180 minutes with a yield of liquid fuel products of 43.77% with a heating value of 19750 Btu / lb.
3. The temperature of the pyrolysis process optimal degradation of plastic bottle waste occurs at a temperature of 170 oC and the resulting liquid fuel consists of two types namely BBC 1 kerosene equivalent and BBC 2 premium equivalent with each heating value of 19216 Btu / lb and 19754 Btu / lb.

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5.2. Suggestion

Research needs to be done on the possibility of breaking the heavy hydrocarbons produced by wax products which amount to 31.97% in order to increase the yield of liquid fuel produced.

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