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Plastic, Rubber, And Styrofoam Waste Management As Alternative For Green Energy

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Abstract

Plastics, rubber tires, and styrofoams are commonly used as disposable materials in our society, which contribute to the constant buildup of waste accumulation. A method called waste pyrolysis is able to transform the aforementioned waste into fuels. This method was performed at a temperature of 350 - 500°C with variations of styrofoam decoy mass is 50 gram, 100 gram, 150 gram, 200 gram, and 250 gram and for tire, decoy mass is 500 gram, 750 gram, 1000 gram, 1250 gram, and 1500 gram. A decoy mass variation that produces the highest yield production is subjected to catalyst addition. Active zeolite catalyst with 2%, 4%, 6%, 8%, and 10% content level was added to each material in order to obtain the volume of pyrolysis result. In this research, we got the optimum decoy mass of 200 grams with 84% yield for styrofoam and 750 gram with 32,67% yield for the tire. The optimum catalyst percentage for pyrolysis oil volume derived from styrofoam is 6% with 90% yield and the optimum percentage for the volume of tire-derived pyrolysis oil is 10% with 45,33% of yield. Based on the density and viscosity of conventional fuels, biodiesel has the most similar characteristic to our result. And based on the flashpoint, fire point, and calorific value of conventional fuels, the one with the closest characteristic is kerosene. The utilization of styrofoams and used tires waste for pyrolysis will reduce contamination caused by waste materials that are difficult to degrade in the environment. This research also proved that the fuel oil produced from pyrolysis can be an alternative energy source to fossil-fuel derived energy, notably for biodiesel and kerosene.

Keywords: Pyrolysis, Styrofoam, Tire, Oil, Zeolite

I. INTRODUCTION

Non – degradable materials such as plastics, styrofoam, and tires are getting more common for daily use. Styrofoam has superiority over other material as it is practical, durable, light-weight, and is ideal to act as a vibration barrier for electronic appliances packaging. Those properties had made the styrofoam demands keep being on the rise, causing garbage buildup in consequence of its usage as disposable items.

Land transportation vehicles such as passenger cars, trucks, buses, and motorcycles are getting more common. The growth rate of total motor vehicles in Indonesia provided in Table 1 manifest this phenomenon.

Table 1. Total Motor Vehicles

No.	Type	Unit	Year				
			2014	2015	2016	2017	2018
1	Passenger Car	Unit	11.561.123	12.424.358	13.278.197	13.589.328	17.072.359
2	Bus	Unit	1.979.848	1.998.032	2.003.187	2.010.113	2.039.037
3	Freight Car	Unit	5.570.987	5.907.169	6.248.771	6.368.534	6.888.694
4	Motorcycle	Unit	94.243.031	100.457.355	106.538.948	108.594.712	114.785.638
	Total		113.354.989	120.786.914	128.069.103	130.562.687	140.785.728

Source: Ditjen Hubdat, 2020

Based on data from 2014 to 2018 shown in the table, the total growth of motor vehicles during the 2014 – 2018 period almost reached 25%. The highest total number and growth occur in the motorcycle category with the percentage reached more than 25%. The rising number of motor vehicles had affected the waste buildup of used tires coming from that means of transport.

The usage of disposable styrofoams and tires which is designed for short-term use gives rise to the buildup of waste that is certainly not environmentally friendly. The styrofoam washout in rivers will disturb the balance of the water ecosystem, and direct incineration is going to create air pollution and health concern. Waste accumulation of tires and styrofoams would need a really long time to be completely degraded by microbes in the soil. Therefore, we need a proper measurement to treat the waste, one of which is pyrolysis technology. In addition, fuel oils as the result of pyrolysis can provide alternative energy, substituting the one from fossil fuels of which the reserve has been decreasing and is environmentally irresponsible.

Pyrolysis is a polymer degradation process at high temperatures. The pyrolysis takes place in a non-oxidative condition, which is a condition that does not require oxygen in the process. Pyrolysis is able to produce valuable products, such as fuel oils (Scheirs, 2006). The research about pyrolysis producing fuel oils has been introduced/conducted/performed/carried out by many researchers (Islam dkk., 2013; Ayanoglu & Yumrutas, 2016) who try to get the optimum result.

II. LITERATURE REVIEW

Polystyrene (IUPAC Poly (1-phenylene-1,2-dial)), is a polymer with the monomer styrene, a liquid hydrocarbon made commercially from petroleum. The first polystyrene product to be produced for commercial use was the styrene homopolymer, also known as crystalline polystyrene. Crystalline polystyrene is also known as General Purpose Polystyrene (GPPS), which is more heat resistant to other thermoplastic polymer products. Another polystyrene product that is no less important is polystyrene with rubber modifications or High Impact Polystyrene (HIPS). This HIPS product is opaque, harder, and easier to manufacture than other thermoplastic polymer products.

The use of polystyrene is quite wide, including as an insulator or coating material on wires or cables, resins, plastic household appliances, bottles, children's toys, CD and DVD cases, furniture, and so on. However, currently, Indonesia does not have a polystyrene factory with sufficient capacity to meet domestic needs, so it can still be used by other countries such as China, the United States, Germany, Taiwan, and others. Based on these facts, the establishment of polystyrene factories in Indonesia is very prospective (Nurhayati, 2016).

There are two kinds, namely rigid and foam. Rigid PS is clear, glassy or opaque, rigid, brittle, fat and solvent, malleable, softens at 950C. PS natural foam is like foam, usually white, soft, brittle, fat, and solvent. Oil refineries are the main producers of polystyrene because the main raw material for polystyrene is a hydrocarbon compound. Polystyrene is formed from its own monomers. The nature of styrene compounds is a colorless liquid and is almost similar to benzene compounds with the chemical formula C6H5CH = CH2 (C8H8) (Salamah, 2018). Styrofoam has a melting point of 820C - 1030C and a critical point of 0C.

Latex is a hydrocarbon polymer that is formed from a milky emulsion in the sap of several plant species but can also be produced synthetically (Ali, 2009). Latex is found on the skin, leaves, and rubber seed integument. Latex is obtained from the Hevea brasiliensis plant, processed and traded as an industrial material in the form of sheet rubber, crepe, concentrated latex, and crumb rubber. The latex released by rubber trees has a milky white to yellow color. Latex contains 25-40% raw rubber material (crude rubber) and 60-77% serum (water and soluble substances). Raw rubber contains 90-95% pure rubber, 2-3% protein, 1-2% fatty acids, 0.2% sugar, 0.5% salt from Na, K, Mg, P, Ca, Cu, Mn, and Fe. Natural rubber is a hydrocarbon which is a polyisoprene (C5H8) n macromolecule with the chemical formula 1,4-cispoliisoprene. The rubber particles are suspended or evenly distributed in the latex serum with a size of 0.04-3.00 microns with a round to oval particles (Triwijoso, 1995).

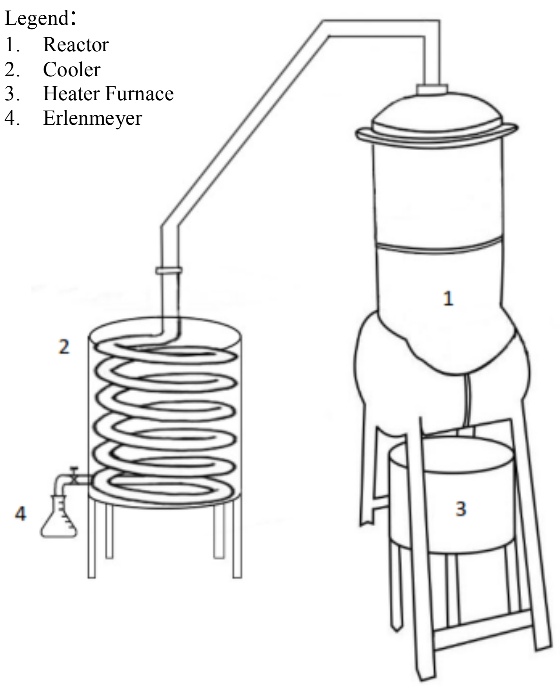
Styrofoam generally has a pure white color, is simple and light in shape. Styrofoam, which is made from styrene copolymer, is a food business choice because it prevents leakage and retains its shape when held. In addition, this material is also able to retain heat and cold but still comfortable to hold. The basic material of Styrofoam is polyester, a type of plastic that is very light, stiff, translucent, and cheap but brittle quickly. Because of these weaknesses, polystyrene is mixed with zinc and butadiene compounds. This causes the polystyrene to lose its clear properties and change color to milky white. Styrofoam is not actually the name of the plastic packaging in question. Styrofoam is a trademark name of the Dow Mechanical company. Styrofoam itself is a plastic package made of a polymer which consists of many types such as polyethylene tereflatate (PET), polyethylene chloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS), polycarbonate, (PC), and melamine.

Styrofoam is made from the main ingredient of polystyrene, which is a fairly strong plastic material composed of n-butane or n-pentane and benzene. This material is processed by injection into a mold with high pressure and heated at a certain temperature and time. Styrofoam or expanded polystyrene is commonly known as white cork which is generally used such as food and beverage containers, electronic goods safety packaging, machines and glassware, decorations, and so on. The material from this Styrofoam is non-recyclable and non-biodegradable (it cannot decompose into constituents).

Styrofoam can be re-processed into fuel. The processes used include pyrolysis, hydrocracking, and hydroisomerization. However, these processes require assistance in the form of a catalyst in increasing the composition and yield of the product. Products produced from the pyrolysis, hydro-cracking, and hydroisomerization processes are syngas, liquid (oil), and some products in the form of solids (char) (Angga, 2013). In the results of the styrofoam pyrolysis process, it contains several groups of compounds including styrene, toluene, aldehyde, isopropyl benzene, diphenyl, alcohol, and carboxylic acids (Salamah, 2018).

III. RESEARCH METHODOLOGY

This research used styrofoam, inner tire, and zeolite-based material as catalysts. The sketch/picture of the instrument installation we use in this research is depicted in Figure 1.



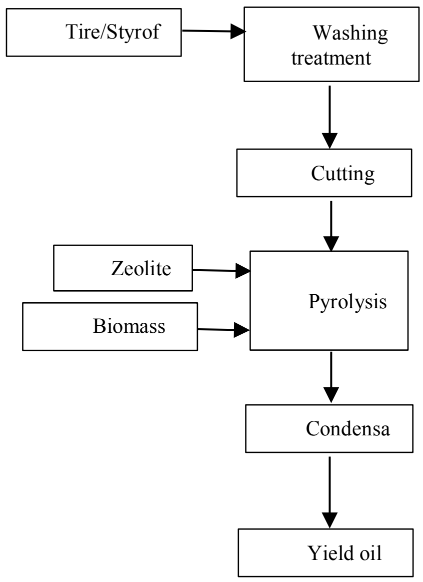


Figure 1. Installation of the instrument in this research Figure 2. The workflow of the pyrolysis process

Raw materials in pyrolysis, tire, and styrofoam, were washed first to get rid of impurities on the surface of materials. Then we reduced its size by cutting the material up to less than 2 cm to widen the contact surface during the pyrolysis process.
The pyrolysis process was conducted following the procedure depicted in Figure 2, where it was performed at a temperature of 350-500 ^{0}C. The variations of styrofoam decoy mass are 50 gram, 100 gram, 150 gram, 200 gram, and 250 gram and the variations of tire decoy mass are 500 gram, 750 gram, 1000 gram, 1250 gram, and 1500 gram. We picked a variation of decoy mass that has the highest yield from this step, then added a zeolite catalyst in order to obtain the volume of pyrolysis product. Active zeolite catalyst with 2%, 4%, 6%, 8%, and 10% content level was added to each material.

IV. RESULT AND DISCUSSION

The result of this research shows an optimum decoy mass of 200 grams for styrofoam with a yield of 84% and 750 grams for a tire with a yield of 32.67% as provided in Table 2.

Table 2. Pyrolysis Result of Styrofoam and Tire

No.	Styrofoam			Tire		
	Mass (gram)	Volume (ml)	Yield (%)	Mass (gram)	Volume (ml)	Yield (%)

1	50	37	74	500	160	32
2	100	78	78	750	245	32,67
3	150	115	76,67	1000	314	31,4
4	200	168	84	1250	366	29,28
5	250	205	82	1500	412	27,47

Catalyst addition was performed and the control variable is the decoy mass of styrofoam and tire that gives the highest yield from the pyrolysis process. Based on Table 2, we use a decoy mass of 200 grams for styrofoam and 750 for the tire. Table 3 shows that the optimum zeolite catalyst percentage is 6% in order to obtain the volume of pyrolysis oil derived from styrofoam with a 90% yield and catalyst of 10% for tire-derived pyrolysis oil with a yield of 45.33%.

Table 3. Catalyst addition to pyrolysis result

No.	Kadar Katalin (%)	Styrofoam		Ban	
		Volume (ml)	Yield (%)	Volume (ml)	Yield (%)
1	0	168	84	245	32,67
2	2	172	86	264	35,2
3	4	177	88,5	276	36,8
4	6	180	90	300	40
5	8	179,6	89,8	331	44,13
6	10	178	89	340	45,33

Figure 3 introduces the relation between catalyst level and fuel density, and Figure 4 shows the relation between catalyst level and fuel viscosity. Based on density and viscosity, conventional fuel that have the most similar characteristics with pyrolysis result in this research is biodiesel.

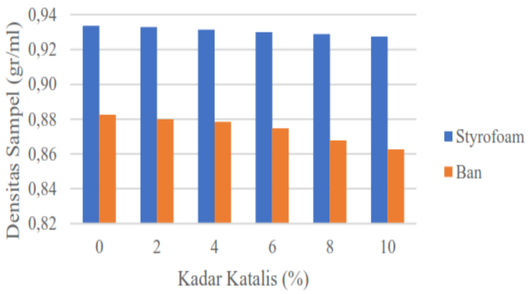


Figure 3. The relation between catalyst percentage and density

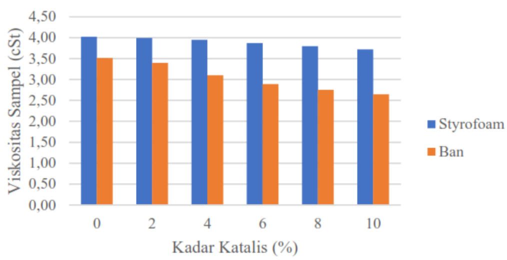


Figure 4. The relation between catalyst percentage and viscosity

According to oil fuel specification data by PT. Pertamina, the kinematic viscosity of diesel is in the range between 2 – 4.5 CST thus both pyrolysis oil in our research satisfy the oil fuel specification for diesel type.

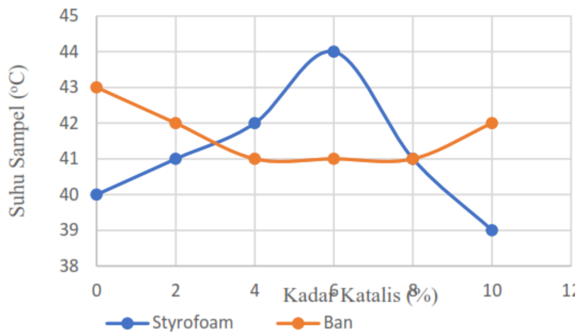


Figure 5. The graph between catalyst percentage and flash point

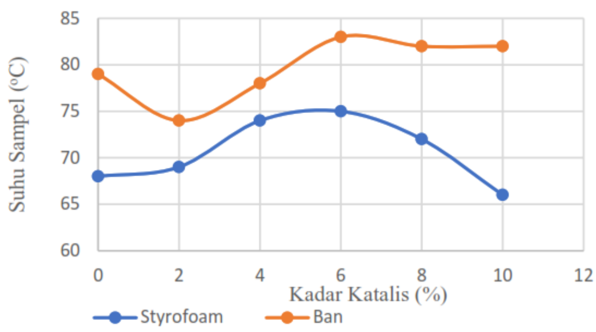


Figure 6. The graph between catalyst percentage and fire point

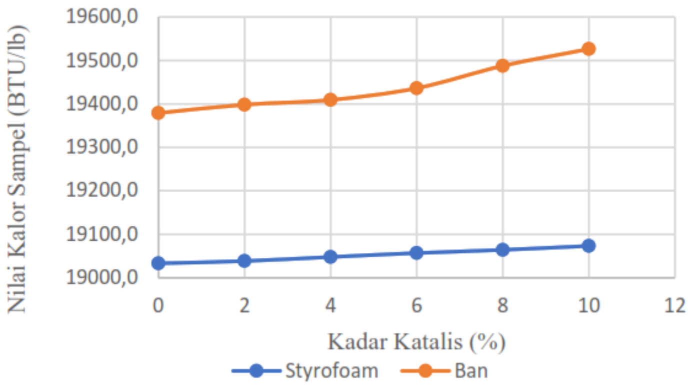


Figure 7. The graph between catalyst percentage and calorific value

On the other side, based on the flashpoint and fuel calorific value of pyrolysis oil provided in Figures 5, 6, and 7, the conventional fuel whose characteristic most similar to it is kerosene. A higher calorific value shows higher quality fuel as it will generate high heat when used. If we compare it to the calorific value of fuel oil in the market, both pyrolysis oils obtained in our research have a calorific value close to kerosene with a value of 19784,960 BTU/lb.

V. CONCLUSION AND FURTHER RESEARCH

In this research, we found the optimum decoy mass for styrofoam pyrolysis is 200 grams with 84% yield and 750 grams for tire pyrolysis with a yield of 32.67%. The optimum zeolite catalyst percentage for pyrolysis oil volume is 6% with a yield of 90% for styrofoam and 10% with a 44.13% yield for the tire. Based on the density and viscosity of conventional fuels, the fuel with the most similar characteristics to our result is biodiesel. And based on the flashpoint, fire point, and calorific value of conventional fuel, kerosene is the one with the closest characteristics.

The utilization of styrofoam and used tire waste in the pyrolysis process will reduce pollution caused by non-degradable waste materials in our environment. This research also proves that fuel oils from the pyrolysis process can be used as an alternative to fossil fuel energy of biodiesel and kerosene.

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