Effect of Time on Catalytic Pyrolysis of Waste Motorcycle Tires (IRC) Using Fly Ash Catalyst Fiber and Palm Shell to Improve the Quality of Pyrolysis Oil

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Abstract

Used tires are waste that comes from vehicles that are no longer in use , outer tires are made from rubber as a basic material, one type of which is a synthetic polymer which makes used tires difficult to decompose in nature, a synthetic one which contains isoprene, styrene and butadiene polymers. Meanwhile, supporting materials include activators, anti-oxidants, softeners and carbon black. The materials contained in these tires mean that waste tires will not biodegrade easily. Therefore, we can process outer tire waste through a pyrolysis process to produce pyrolysis oil.Pyrolysis technology is considered one of the most promising recycling strategies and has wide applications in the fields of biomass, waste and coal. Pyrolysis of waste motorbike tires in conditions free of oxygen and atmospheric pressure can produce high-value fuels and chemicals (limonene, isoprene) contained in TPO. The POFA (palm oil fuel ash) catalyst will be activated using ESP (egg shell powder) which aims to increase the CaO or calcium content, where egg shells have slightly greater porosity and calcium as a catalyst activator which can produce pyrolysis oil. Used tire waste will be converted into pyrolysis oil products using shell fly ash and palm fiber catalysts, in order to improve the quality of liquid fuel products from used tire waste with 5 time variation of 2,3,4,5,6, and each temperature of the time variation is 550°C in a batch reactor.

Keywords: *pyrolysis oil, egg shell powder (ESP), thermochemistry, palm oil fuel ash (POFA), batch reactor, limonene & isoprene*.

1. Introduction

Used tires are waste that comes from vehicles that are no longer in use. According to Maryoto (2010), in Indonesia the amount of used outer tire waste per year is very large, namely it can reach 11 million tons per year. This number could continue to increase along with the continuous increase in tire production in Indonesia in large quantities to meet the production stock of the vehicle industry in Indonesia, making the amount of used tire waste in Indonesia continue to increase.

Outer tires are made from rubber as a basic material, one type of which is a synthetic polymer which makes used tires difficult to decompose in nature, a synthetic one which contains isoprene, styrene and butadiene polymers. Meanwhile, supporting materials include activators, anti-oxidants, softeners and carbon black. The materials contained in these tires mean that waste tires will not biodegrade easily. Therefore, we can process outer tire waste through a pyrolysis process to produce pyrolysis oil.

Kholidah (2018), states that pyrolysis is a thermal degradation process of solid materials in limited air or oxygen conditions. Pyrolysis is also described as a cracking or cracking process. The cracking or cracking process has two types, namely, thermal cracking and catalytic cracking. Thermal cracking is a cracking process using high pressure and temperatures ranging from 350ºC to 900ºC without using a catalyst, while using lower temperatures and pressure in the presence of a catalyst is called catalytic cracking.

The main components of TPO (tires pyrolysis oil) are alkenes, diolefins, and aromatic hydrocarbons, as well as impurities such as PAHs, sulfides, and nitrides. Recently, one of the promising processing methods proposed to increase economic feasibility is to produce high – value chemicals (mainly limonene and isoprene) by increasing their content in TPO and then using the remaining TPO for energy recovery. Limonene is the most abundant compound in TPO (Chen et al, 2022).

In this research, used tire waste will be converted into pyrolysis oil by using palm fiber fly ash as a catalyst, where the catalyst is activated using egg shell powder which aims to increase the calcium content which aims to improve the quality of the pyrolysis oil. The addition of eggshell powder is very important as a catalyst activator because the presence of CaO has been investigated in plastic waste, tire waste, biomass and coal, which shows that CaO participates in many enhancement reactions to increase the selectivity of valuable

products and contains isoprene and limoene, in order to improve product quality. Pyrolysis oil from used tire waste, in varying times of 2, 3, 4, 5, 6 hours at a temperature of 550 ℃.

2. Literature Review

2.1 Waste Motorcycle Tires

Used tires contain many useful components (especially rubber and carbon black), so they have the potential to be recycled by thermo-chemical techniques to produce high-value chemicals and fuels. Pyrolysis technology is considered one of the most widely used in promising recycling strategies and has wide applications in the field.

Picture 1. picture of the outside of the tire

In general, the compound composition of tires is dominated by carbon black which is used to strengthen the rubber and help with scratch resistance. Then, during the tire vulcanization process, sulfur compounds are added to bind the polymer to the rubber and also to strengthen and prevent changes in tire shape due to high temperatures (Hutomo and Winarno, 2015).

Table 2.1 Chemical content of motor vehicle tires

No	Jenis	Hasil
1	Natural Rubber	25%
2	Butadiene Rubber	15%
3	Butyl Rubber	5%
4	Carbon Black	35%
5	ZnO	4%
6	Oil/Naphthene/Aromatic	4%
7	Dirt/Dust/Kaolin/Calcium	12%

(Source: Arita , dkk. 2015)

Used tires containing rubber are a type of polystyrene (synthetic polymer) which can be processed using a cracking process. In this research, the process of producing liquid hydrocarbons from polystyrene is carried out using a catalytic pyrolysis process which takes place at high temperatures. Pyrolysis or pyrolysis is the process of decomposing biomass (lysis) due to heat (pyro). So pyrolysis is a decomposition event that occurs due to heat.

2.2 Impact of Waste Tires

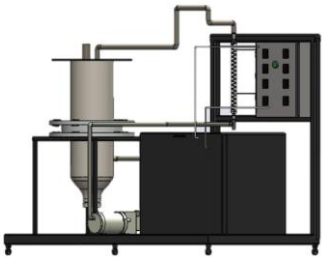
Outer tires are made from rubber as a basic material, one type of which is a synthetic polymer which makes used tires difficult to decompose in nature, a synthetic one which contains isoprene, styrene and butadiene polymers. Meanwhile, supporting materials include activators, anti-oxidants, softeners and carbon black. The materials contained in these tires mean that waste tires will not biodegrade easily. Especially polystyrene cannot be easily recycled so polystyrene waste processing must be done correctly so as not to harm the environment. Rubber-based tires are a type of synthetic polymer. Apart from that, eliminating used tire waste by burning is also less effective and risky because it can cause pollutants from exhaust emissions and other polluting particles. Meanwhile, if it is thrown away carelessly, it will cause blockages in drainage channels which will cause flooding (Falaah and Cifriadi, 2012).

2.3 Pyrolysis

According to Kholidah (2018), states that pyrolysis is a thermal degradation process of solid materials in limited air or oxygen conditions. Pyrolysis is also described as a cracking or cracking process. The cracking or cracking process has two types, namely, thermal cracking and catalytic cracking. Thermal cracking is a cracking process using high pressure and temperatures ranging from 350ºC to 900ºC without using a catalyst, while using lower temperatures and pressure in the presence of a catalyst is called catalytic cracking. The conversion process of pyrolysis is starts from drying and affects the quality of the product to be produced, then the gas formed contains many compound elements which are then separated by a condensation process so that oil and gas are produced. There are several methods that can be used to convert plastic waste into liquid fuel, including: pyrolysis, thermal cracking, and catalytic cracking. Among these three methods, the pyrolysis method is the method that is considered the most promising.

2.4 Catalytic Cracking

Catalytic cracking is a cracking process using a catalyst in the reaction. Cracking is the process of breaking the bonds of a substance where complex organic molecules become simpler, catalytic cracking leads to the formation of gases, liquids and residues. The use of catalysts is divided into 2, namely heterogeneous catalysts and homogeneous catalysts, where heterogeneous catalysts are easier to separate from the reaction medium but difficult to deactivate, while homogeneous catalysts are difficult to remove from the final product so that the catalyst often becomes sludge after the reaction process (Pratiwi, 2010).



Picture 2. Reactor Batch

2.5 POFA (palm oil fuel ash)

The POFA (palm oil fuel ash) catalyst will be activated using egg shell powder which aims to increase the CaO or calcium content, where egg shells have slightly greater porosity and calcium as a catalyst activator which can produce pyrolysis oil and chemicals. high value (especially limonene and isoprene) by increasing their content in TPO. (Fu et al, 2016).

Picturre 3. POFA From PT. Bayungagrosawita

Palm oil industry processing waste, one of the energy sources that produces biomass from the waste of empty palm fruit bunches, palm shells and palm fiber. That with the addition of the CaO catalyst it is hoped that the amount of solid residue will be reduced. According to Haspiadi (2015), generally the type of solid waste from industrial processing of palm oil which is widely used as an energy source is a mixture of shells and palm fiber which then produces fly ash from boiler combustion, fly ash It can be used as a catalyst because it contains calcium oxide (CaO) which can improve the quality of pyrolysis oil.

2.6 ESP (Egg Shell Powder)

Egg shells are solid waste resulting from processing food and agriculture most of the eggshell waste is generally thrown away in the trash without further processing (Mantovani & Kusmiyati, 2017). In recent years, efforts have been made for the application of egg shells as value-added products. Applications of egg shells include as a bone substitute, a basic material for calcium phosphate bioceramics, for example, hydroxyapatite (Mutmainnah, 2021), and a low-cost adsorbent to remove ionic pollutants.

Picture 3. Egg Shell Powder

Egg shells have slightly greater porosity and calcium as an important element. The chemical composition of eggshell has been reported as follows: calcium carbonate (94%), magnesium carbonate (1%), calcium phosphate (1%) and organic matter (4%). Due to the hard basic structure of egg shells, the high calcium content. Therefore, egg shell powder (Egg Powder shell) can be used to activate palm fiber fly ash as a catalyst (Katsiroh & Kusmiyati, 2017).

3. Research methods

3.4.1. Research Procedure

The flow diagram of this research procedure

Figure 3.1. Research Procedure Flow Chart

In this research, the process begins with the preparation of raw materials, namely waste motorbike outer tires. After that, proceed with catalyst preparation and pyrolysis to get the desired results of pyrolysis oil. Then data analysis is carried out to obtain conclusions from the research conducted.

3.4.2. Raw Material Preparation

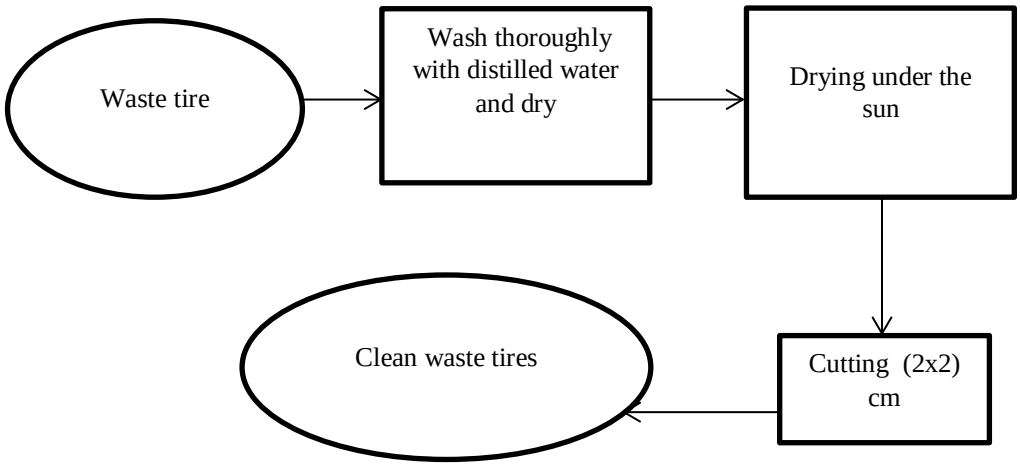
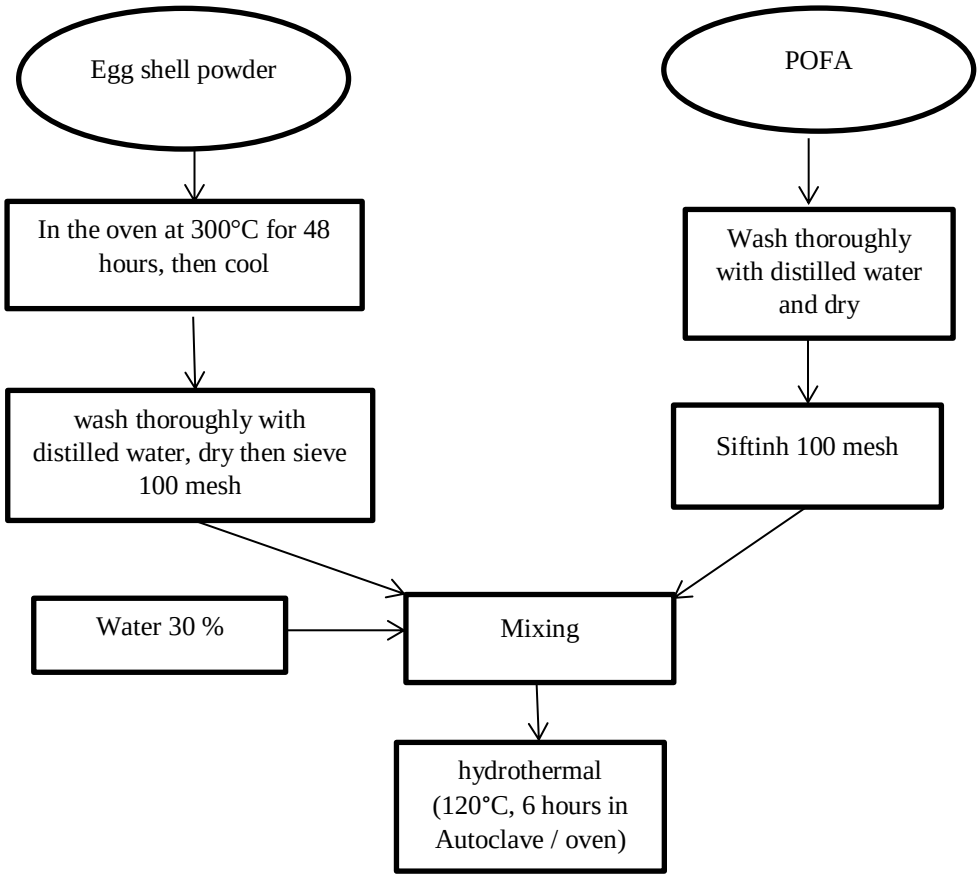


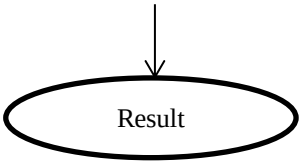
Figure 3.2. Pre-Treatment Flow Diagram for waste motorbike outer tires

The raw material preparation process starts from washing until the washing water looks clean without the slightest dirt, after that it is dried in the sun until dry and a cutting treatment is carried out with a size of 2x2 cm, so that it is easier to put into the batch reactor.

3.4.3. Activation of shell fly ash and palm fiber

3.4.3.1. Hydrothermal Process





Picture 3.3. Hydrothermal Process

In the hydrothermal process, 5 kilograms of POFA and 2.5 kilograms of eggshell powder as an activator are mixed using a mixer with a ratio of 2:1, then put into an autoclave at a temperature of 120°C for 24 hours.

3.4.3.2. Calcination process

Calcination process flow diagram

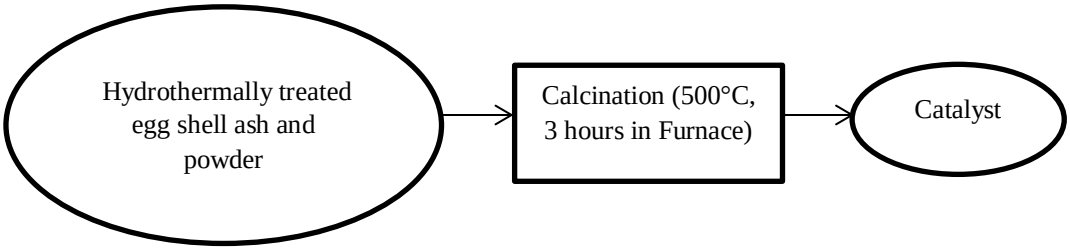


Figure 3.4. Catalyst Calcination Flow Diagram

In the calcination process, 7.5 kilograms of catalyst that has gone through a hydrothermal process is then put into the furnace at a temperature of 700°C for a processing time of 3 hours.

3.4.4. Pyrolysis

Pyrolysis process flow diagram

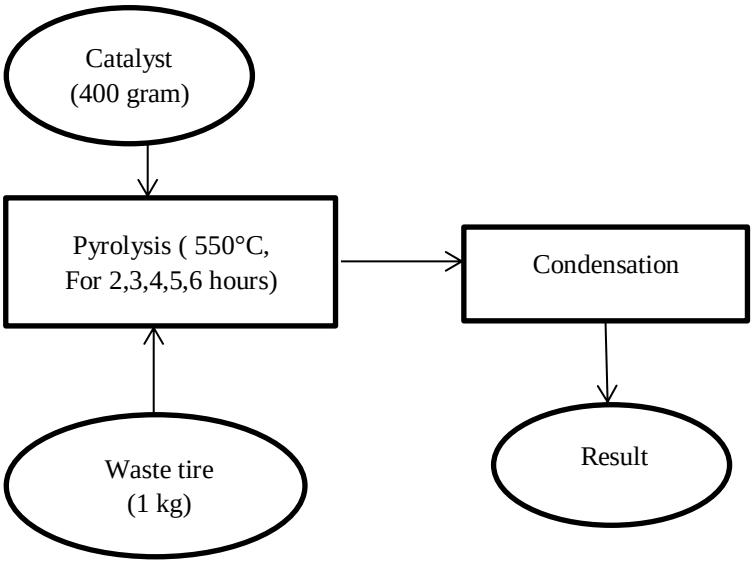


Figure 3.5. Pyrolysis Process Flow Diagram

The reactor contains a mixture of outer tire waste and catalyst, then a catalytic cracking process is carried out (550°C, for 2,3,4,5,6 hours) and the results of this pyrolysis are solids and gas which will be condensed into liquid.

3.4.5. Distillation of Pyrolysis Results

Flow diagram of distillation of pyrolysis results

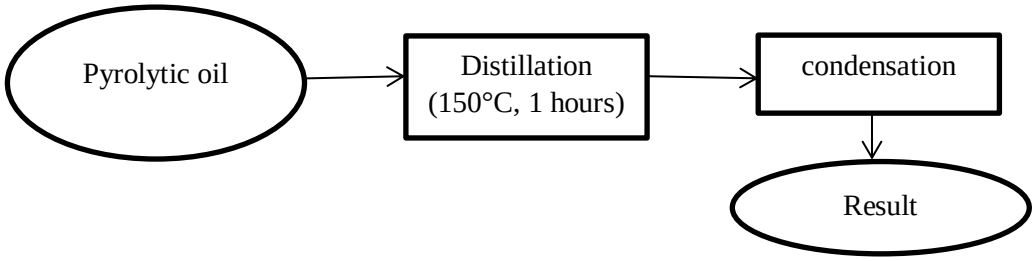


Figure 3.6. Distillation Flow Diagram

The liquid resulting from pyrolysis of each variable is distilled at a temperature of 150°C to obtain pyrolysis oil.

3.4.6. Comparison of pyrolysis oil results based on the type and weight of catalyst

Table 2.3 Comparison of pyrolysis oil results based on the type and weight of catalyst

Material (gr)	Type of Catalyst	Temperature (℃)	Yield (mL)	Reference
3000 (tire)	Natural zeolite 180 gr (Catalytic Cracking)	400	1232	Lince et al (2015)
500 (tire)	Spent RCC 400 gr (Catalytic Cracking)	200	71	Handono (2017).
250 (tire)	Aluminum Oxide 15 gr (Catalytic Cracking)	250	40,25	Kholidah (2018)

500 (tire)	Natural Zeolite 400 gr (Catalytic Cracking)	200	73,5	Arita et al. (2015)
250 (Palm kernel oil)	Palm ash (Transesterification)	60	174	Yoeswono et al. (2007)
Waste tire	POFA	600	(Pyrolysis oil isoprene & limoene) 150	Chen et al. (2022)

Reference

Anam, Choirul. Sirojudin et al. (2007). Functional Group Analysis in Test Samples, Gasoline and Spirits Using the FT-IR Spectroscopy Method. Periodic Physics. 10(1). 79-85.

Arita, S., Assalami, A., & Naibaho, D. I. (2015). The process of making liquid fuel by utilizing used tire waste using a zeolite catalyst. Journal of Chemical Engineering, 21(2), 8-14.

Chen, Quan et al. 2022.Influence of CaO on the thermal kinetics and formation mechanism of high value-added product during water tire pyrolysis.Jornal of Hazardous Material.2-5.

Damayanthi, R., & Martini, R. (2009). Process for Making Liquid Fuel by Utilizing Used Tire Waste Using Zeolite Y and ZSM-5 Catalysts.

Falaah, A. F., & Cifriadi, A. (2012). Utilization of Used Tire Waste Using Pyrolysis Technology. Perkaretan News, 31(2), 103-107.

Haspiadi and Kurniawaty. (2015), Utilization of solid waste from palm oil shell ash and palm fiber from boilers for manufacturing light concrete bricks. Utilization of solid waste of palm oil fuel ash from boilers for manufacturing light concrete bricks. Industrial Technology Research Journal.Vol.9 No.2 (1-2).

Hidayati, N. Asro. and Laelani, I. (2016). Study of the Use of Boiler Ash on the Increase and Yield of Tomatoes on Various Planting Media. Science Media Journal. Vol 9 (2).1.

Hikmawan, O. Marisa, N. and Lia, H, M. (2020). Utilization of Palm Oil Shells and Fiber as Boiler Fuel. Industrial Journal. 18-19.

Juwita, Leni. (2003). Material Characterization Using XRF, XRD and SEM-EDX. Engineering Journal. Vol 2(2). 2.

Katsiroh, F. & Kusmiyati, S.T. 2017. Effect of Methanol Oil Molar Ratio on Biodiesel Conversion from Used Cooking Oil with Modified Eggshell CaO Catalyst Preparation.

Li et al. (2016). Derived oil Production by catalytic pyrolysis of scrap tires. Chinese Journal of Catalysis.Vol.37.(3-5).

Marsyahyo, Eko. (2009). Brunnaeur Emmet Teller (BET) Analysis of Hemp Fiber (Boehmeria nivea) Surface Topography for Strengthening Media in Composite Materials. Fly Wheel Journal. Vol. 2 No. 2 (2-4).

Mutmainnah, M. 2021. Synthesis of hydroxyapatite from duck egg shells with precipitation method for bioceramics applications.

Saputra, Ade. Manggalla, L, K. and Salimin. (2022). Utilization of Used Tire Pyrolysis Oil to Become an Alternative Fuel. Scientific Journal of Mechanical Engineering Students. Vol 7(1).1-3.

Zainudin, M. (2021). Flame Test Analysis of Waste Tire Distillation Results. Crankshaft Journal.Vol.4 No.2 (38-39).