Liquid Oil Synthesis Using Pyrolysis with Natural Zeolite Catalyst

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Abstract—**Currently, the rapid population growth is increase makes fuel needs increases and fuel availability's increasingly limited. Utilization of LDPE and PP plastic waste can be an alternative in processing waste into fuel. This research aimed to analyze effect of using calcined natural zeolite catalyst and plastic composition on the pyrolysis oil product characteristics. Pyrolysis was carried out for 4 hours at a temperature of 325^0C on LDPE and PP plastic waste to produce oil. Plastic composition for pyrolysis consist of LPDE 100%, LDPE 75%: PP 25%, and LDPE 25%: PP 75%. The mass of the catalyst used in the pyrolysis process is 0.75 kg. Pyrolysis oil product test parameters consisting of density, flash point, kinematic viscosity, caloric value, and chemical composition. The results of this study indicate that increase the PP composition in the pyrolysis process tends to cause a decrease in oil yield. The maximum oil yield obtained was 23.03% in sample with LDPE 100%. The characteristics of the pyrolysis oil were obtained including a density of $743-753$ kg/m^3, a viscosity of 0.417−0.442 cSt, a flash point of 26.94-27.22^{o}C, a caloric value of 45.73−45.98 MJ/kg. Hydrocarbon content of pyrolysis oil light fraction has similarities to hydrocarbon content of gasoline which is composed of C_4-C_{11} carbon atoms.**

Keywords – *Pyrolysis, Plastic Waste, Natural Zeolite, Pyrolysis Oil, Catalyst.*

I. INTRODUCTION

Increasing human populations, lifestyle changes, and increasing economic growth have caused world's rate of plastic production and consumption to accelerate. The use period of plastic use is a factor that causes an increase in plastic waste every day. World plastic production has reached 300 million tons per year and is estimated to increase continuously [1]. Usually, plastics are produced using raw materials from petroleum with additives such as flame retardants, stabilizers, and oxidants to produce stable properties and are difficult to degrade by the environment [2]. Plastic products generally consist of various polymers types, viz. polypropylene (PP), polyethylene (PE), polystyrene, polyvinyl chloride (PVC), polyamide, polyethylene terephtalate (PET) and so on [3].

Handling plastic pollution can be done using waste recycling methods, but in developing countries plastic waste management is done at landfills. Buildup of plastic waste in landfill has the potential to become a habitat for insects and rodents so that it has the potential to cause disease in humans [4]. Several alternatives that can be used to solve the problem of plastic waste include mechanical, chemical recycling, and energy recovery technology [5]. Pyrolysis process is an energy recovery technology that received significant attention because it is able to convert plastic waste into energy in the form of solid, liquid, or gas economically and environmentally friendly [1].

Pyrolysis is the thermal degradation of plastic waste at temperatures between 300-900°C in an environment without oxygen to produce fuel oil[6]. Some advantages of pyrolysis process include being able to reduce the generation of plastic waste and being able to produce valuable products such as fuel and chemicals. In the pyrolysis process the formation of dioxins can be inhibited

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due to conditions without oxygen [7]. Economically, pyrolysis process has advantages over plasma arc incineration and gasification technologies with low annual capital costs (17−25 dollars/ton) and low net operating costs (2-3 dollars/ton) along with liquid fuels and chemical products of economic value [8].

Several parameters that affect the quality and yield of the pyrolysis process include plastic composition, reactor type, and operating conditions such as reactor temperature and reaction time. In addition, the pyrolysis process can be carried out under reaction conditions with or without the presence of a catalyst [9]. The presence of a catalyst in the pyrolysis process has advantages such as increasing the targeted reaction rate, reducing reaction time and temperature, improving the quality of oil products, and improving process efficiency [10]. Catalyst characteristics such as surface area, particle size, pore size, pore volume, and acidity play an important role in the pyrolysis process. Several types of catalysts are often used in the pyrolysis process, including ZSM-5, HZSM-5 zeolite-Y, silica-alumina, and the FCC [11]. Catalytic reactions in pyrolysis process include cracking, oligomerization, cyclization, aromatization, and isomerization reactions[10].

Several researchers reported the use of certain catalysts in the pyrolysis process. The use of HZSM-5 catalyst in PE pyrolysis process can increase oil production, with a predominantly aromatic compound and isoalkanes [12]. Ratnasari et al. [13], reported that microporous catalysts can improve liquid oil quality by limiting the entry of heavy hydrocarbons into catalyst. Miskolczi and Ates [11], reported their research results that the use of β-zeolit, y-zeolit, and m-Ni-Mo catalysts in pyrolysis of plastic waste-heavy oil recovery can increase the yield of oil and gas products compared to without a catalyst. Muhammad et al. [3], showed that ZMS-5 pyrolysis and zeolite-y in pyrolysis of electronic plastic waste produced oil products with the main content of benzene, toluene, and ethyl benzene.

Natural zeolite is a material that has high potential if it's developed as a catalyst in pyrolysis process because the amount is quite abundant and is environmentally friendly. Zeolite has a relatively cheaper price than synthetic catalysts. Natural zeolites are often found in several countries such as Japan, America, Indonesia, Saudi Arabia, and Italy [14]. Modernite mineral content in natural zeolite causes a fairly high level of stability when used as a catalyst material for pyrolysis process. However, the direct use of natural zeolite is less effective because it has a relatively low specific surface area, so it's necessary to modify natural zeolite using a heating process to increase the specific surface area of natural zeolite.

Zolite heating process can be carried out at temperatures above 300°C without damaging zeolite initial structure. This shows that natural zeolite has a fairly high stability of the framework structure even though it is formed naturally. In addition, natural zeolite has a high Si/Al ratio. The high Si/Al ratio causes the zeolite to be acidic so that it can improve thermal stability and catalytic conversion process of organic compounds [1]. Based on previous research has shown that modified calcined natural zeolite as a catalyst in pyrolysis of combination of Low Density Polyethylene (LDPE) and PP plastics had not been described in detail by previous researchers.

This study aims to analyze effect of using calcined natural zeolite catalyst and plastic composition on the pyrolysis oil product characteristics. Plastics used in pyrolysis process are Low Density Polyethylene (LDPE) and Polypropylene (PP). Both types of plastic are plastic types that are often used in the community as food packaging.

II. MATERIAL AND METHODS

A. Materials

This research main raw materials include LDPE, PP, and natural zeolite plastic waste measuring 6-8 mesh. LDPE plastic consists of a mixture of 50% plastic bag waste and 50% food packaging plastic waste. PP plastic consists of a mixture of 40% baby diaper plastic, 30% plastic straws, and 30% instant noodle packaging.

B. Method

i. Plastic Waste Preparation

Plastic waste grouping based on type of plastic, viz. plastic bags, plastic food packaging, plastic straws, plastic instant noodle packaging, and plastic baby diapers. In plastic baby diapers, its plastic part separated first from other parts of the diaper such as hydrogel and adhesive. Plastic waste that has been grouped according to its type is then washed using clean water. Cleaned plastic then dried in the sun until dry. Thus, it cut about 1-2 cm^2 in size. Each plastic waste that has been cut is then mixed with all based on type of LDPE and PP. The cut plastic is then weighed according to the variation in plastic composition sample used. Table 1

shows the composition variations used in pyrolysis process.

TABLE I. Composition of plastic waste

Samples	Composition (%wt)
A1	LDPE 100%
A2	LDPE 75% : PP 25%
A3	LDPE 25% : PP 775%

ii.   Natural Zeolite Preparation

Activation of natural zeolite is carried out by the calcination method aimed at removing organic impurities, increase the surface area and pore size A total of 0.75 kg of natural zeolite without any special treatment were weighed and put into a crucible cup. The zeolite was then heated in an electrical furnace at a temperature of $400^{o}C$ for two hours.

iii.   Pyrolysis Experiment

The pyrolysis process of plastic waste (LDPE and PP) is carried out in a fixed bed catalytic reactor with equipment series as listed in Fig. 1. The reactor is made of stainless steel, equipped with an LPG burner, thermocouple, temperature control panel, and condenser. Catalyst holder is placed at the top of reactor tube. Pyrolysis process was carried out by inserting 1.5 kg of plastic samples into reactor tube accompanied by the addition of a catalyst of 0.75 kg. Operating temperature in pyrolysis process is set at $325^{o}C$ for four hours. Gas produced from the pyrolysis process's then flowed through a connecting pipe to the condenser to be cooled using cooling water at a temperature of $17^{o}C$ so that condensate is formed which is accommodated in sample glass.
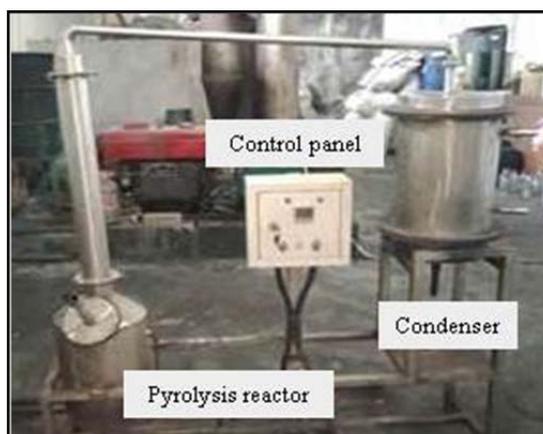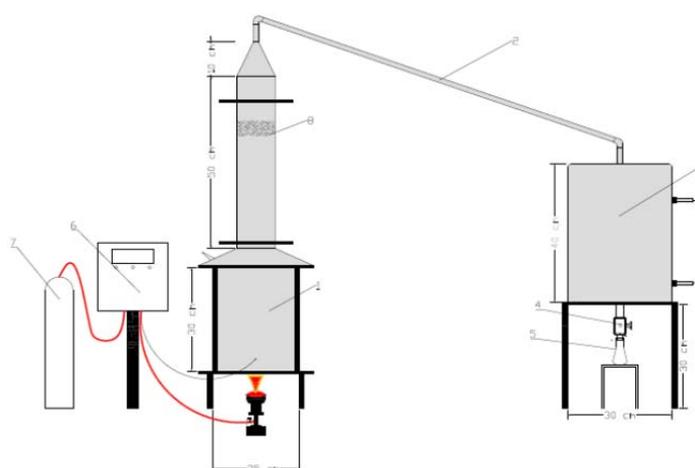

Fig. 1.   Experiment Set Up Pyrolysis of Plastic Waste

Description:

pyrolysis reactor (1); connector pipe (2); condenser (3); liquid product valve (4); sample glass (5); control panel (6); fuel gas (7); catalyst (8).

iv. Characterization

Zeolite morphology before and after calcination was analyzed using Scanning Electron Microscope (SEM Inspect S-50) method which was operated at 20 KV. Crystallinity analysis of zeolite coir using X-Ray Diffraction (XRD PanAnalytical X'Pert Pro). XRD analysis was performed at 10°-90° angle intervals. Zeolite specific surface area was analyzed using the BET (Brunauer-Emmett-Teller Quantachrom) method.

Characteristic tests of oil product obtained from pyrolysis include density (gravimetric method), flash point (ASTM D-93), viscosity ASTM D-445, calorific value (ASTM D-240). Testing the chemical composition of oil samples using GC-MS method (Gas Chromatography-Mass Spectrophotometry Agilent 19091S-433).

III. RESULT AND DISCUSSION

C. Catalyst Characteristic

SEM test results on natural zeolite are shown in Fig. 2. The observations results in Fig. 2 above seen that there are differences between natural zeolite samples before calcination and after calcination. Natural zeolite before calcination had an amorphous shape and a denser pore cavity consisting of non-uniform particles with a particle size of 2.1 μm. Natural zeolite after calcination has a different shape than before. Natural calcined zeolite has an agglomeration form or zeolite constituent particles clump together, causing cavities to form. Voids formed are indicated by yellow arrows in Fig. 2(b) and the particle size is 1.871 μm. The increase in cavities in natural zeolite that has been calcined is due to the decrease in impurities in the zeolite cavity.
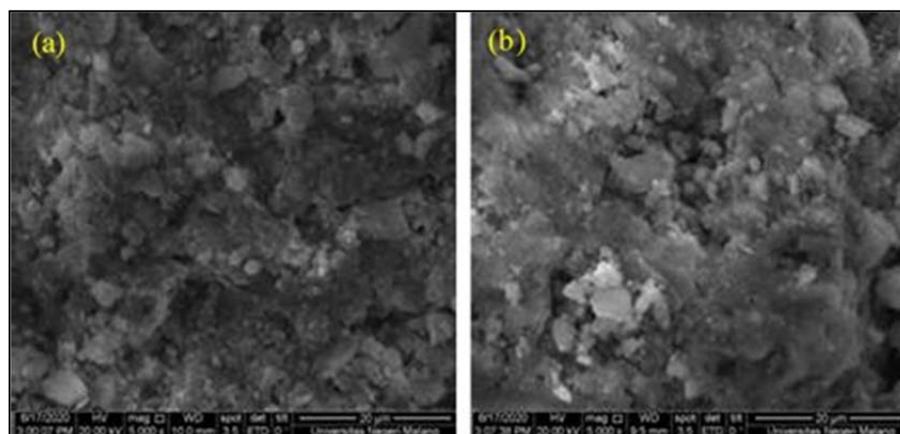

Fig. 2. SEM of natural zeolite before (a) and after activation (b)

SEM A comparison diffractogram of zeolite crystal structure before and after calcination is shown in Fig. 3. XRDresults show that natural zeolite diffractogram before calcination shows more amorphous forms so that crystallinity is lower, while in calcined zeolite shows an increase in crystallinity which is observed based on an increase in peak intensity value.
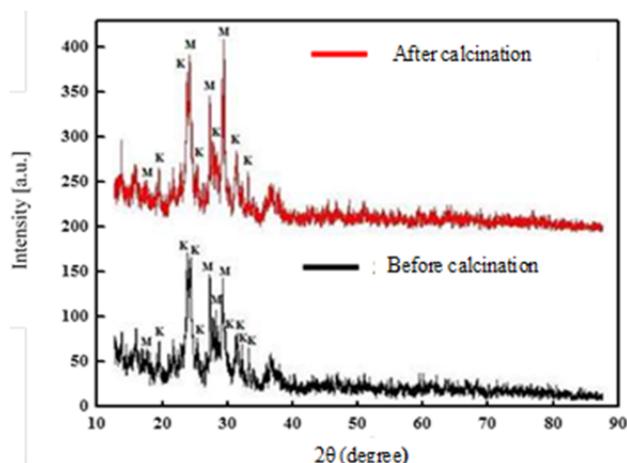
Fig. 3. XRD natural zeolite before and after activation (M=Mordenite, K=Clipnotilolite)

In natural zeolite spectrum that has not been calcined, there is a peak list with a sharp intensity in the 2θ region, including 21.95°; 22.49°; 25.61°; 26.59°, and 27.69°. This shows that clinoptilolite (JCPDS No. 17-0143) as a dominant phase in natural zeolite used with the composition $KNa_2Ca_2(Si_{29}Al_7)O_{72}.24H_2O$. Natural zeolite after being calcined shows a peak list with a sharp intensity in 2θ region, including 22.27°; 25.61°; 27.97°, and 28.03°. Main mineral components of natural zeolite, which were originally dominated by clinoptilolite, have changed after being calcined into the mineral mordenite (JCPDS No. 6-239) with the composition $Na_8(Al_8Si_{40}O_{96}).24H_2O$. This is indicated by the peak of the mordenite identity being the highest intensity peak on the diffractogram.

Calcination treatment can cause an increase in the volume and surface area of the zeolite. This increase was due to the opening of the zeolite pores which were originally covered by impurities and release of water due to the calcination process [15]. The comparison of natural zeolite before and after being calcined is in Table 2.

TABEL 2.   BET of natural zeolite

Parameter	Before calcination	After calcination
Pore specific volume (cc/g)	3.84	5.26
Specific surface area (m²/g)	17.21	23.47
Pore diameter (nm)	1.36	3.38

Based on Table 2 theoretically be explained that adsorption capacity of natural zeolite is directly proportional to the surface area, pore volume, and average pore diameter. The surface area of zeolite after calcination is getting bigger, from 17.21 m^2/g to 23.47 m^2/g. Zeolite pore volume after calcination also increased from 3.84 cc/g to 5.26 cc/g. The larger the pore diameter, the more compounds that can enter and pass through zeolite pores, conversely, the smaller the zeolite pore diameter, the more selective zeolite will be in absorbing or escaping substances that will enter the zeolite pores. Natural zeolite diameter activated by this calcination method has a very small pore diameter of 895 nm so that not many compounds pass through the pores. Similar study results by Atikah [16], that physically activated natural zeolite by calcination resulted in a wider surface area of 31.857 m²/g and a pore volume of 0.124 cc/g. The surface area is larger than the activation result in this study, while the resulting pore volume is much smaller.

D. **Pyrolysis Product**

Fig. 4 shows that increased in pyrolysis time causes an increase in oil products produced. The results showed LDPE plastic had a faster decomposition rate compared to plastic samples with a combination of LDPE and PP. Based on the data above shows that oil volume measurements obtained at pyrolysis time of 60 minutes for samples A1, A2, and A3 amounted to 15, 13, and 0 mL, respectively. The increase in PP plastic composition causes plastic degradation rate to be lower so it tends to produce lower oil volumes. This is cause LDPE plastic has a lower melting point ($124^{o}C$) compared to PP plastic ($220-260^{o}C$).so the heat energy required for LDPE plastic to melt to produce gas is lower than PP [17].
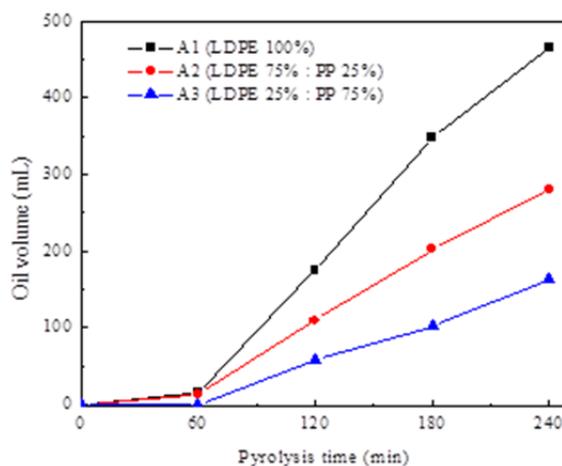

Fig. 4. Volume of pyrolysis oil

Fig. 5 shows the yield obtained from the catalytic pyrolysis of LDPE plastic and combination of LDPE with PP. The pyrolysis of three samples produced products consisting of oil, char, and gas. The low char yield values obtained from the three samples indicated that at a temperature of $325^{o}C$ and a pyrolysis time of four hours, almost all plastic samples had decomposed into gas. The data from the research show that the increase in the composition of polypropylene in the pyrolysis process tends to cause a decrease in oil yield. The maximum oil yield obtained was 23.03% in sample A1 with 100% LDPE composition. The results of this study are similar to those reported by Anene et al. [17], regarding the pyrolysis of LDPE and PP plastics at a temperature of $460^{o}C$ with a batch reactor. The results showed that the yield of oil produced by the pyrolysis of LDPE was higher (96%) compared to the pyrolysis of PP products (86%). Miandad et al. [18] in his research have reported that LDPE pyrolysis and PP plastics with the addition of natural zeolite catalysts. The results showed that the oil yield of the LDPE sample was higher (18%) compared to the oil yield of the PP sample (16%).

Fig. 5 showed that maximum yield of all samples was dominated by gas products. An increase in the composition of the propylene plastic causes an increase in gaseous products yield. The highest yield of gas products was obtained in sample A3 with a composition of 25% LDPE and 75% PP, which was 87.16%. A catalyst presence in pyrolysis process can increase the cracking reaction of pyrolysis gas. This reaction will increase the cracking of long hydrocarbon chains into light hydrocarbon gas so that the yield of gas products increases. In addition, Xue et al. [19] reported that polyethylene monomers tend to have a synergistic effect with PP plastic during the degradation process.
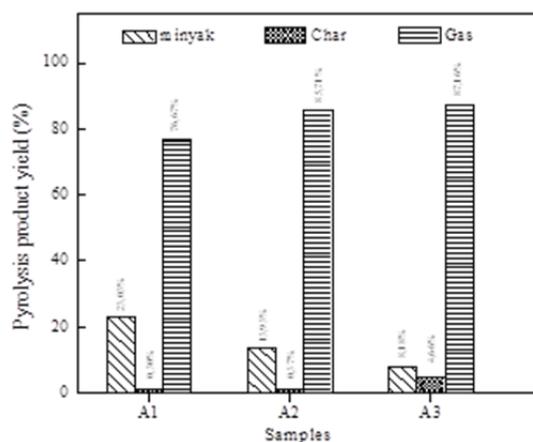
Fig. 5. Pyrolysis product yield

Polyethylene monomers degradation tends to increase the production and transfer of hydrogen thereby increasing the rate of plastic degradation resulting in gaseous products. Similar results reported by Miandad et al. [18] that catalytic pyrolysis process with natural and synthetic zeolite produces higher gas yields compared to oil product yields. The yields of oil and gas products obtained using natural zeolite catalysts were 75.4%, respectively, while the yields of oil and gas products using synthetic zeolite catalysts were 26% and 61.3%, respectively. Obali et al. [20] in his research reported that the use of a mesoporous alumina catalyst in the PP plastic pyrolysis process tends to produce products with higher gas yields than oil product yields.

E. **Oil Product Characteristic**

Table 3 shows testing results of oil products characteristics obtained from LDPE plastic pyrolysis and combination of LDPE and PP. Characteristic testing of oil products performed includes kinematic viscosity parameters, density, heat value, and flash point.

Kinematic viscosity parameter is one of important parameters possessed by fuel oil. The magnitude of the viscosity value used can affect the method of handling, storage, combustion, and combustion. Increased viscosity value causes fuel consumption, engine load, and engine load to be higher. This causes greater engine friction and reduces engine life [21]. Oil product viscosity test showed that the oil product produced by catalytic pyrolysis had a viscosity in the range of 0.417−0.442 cSt. The highest viscosity was obtained by A1 sample with 100% LDPE composition. The addition of polypropylene to samples A2 and A3 tended to decrease the viscosity, but the effect was not significant. Viscosity test showed that it values of the three samples were still lower than the standard diesel and gasoline oils. It viscosity test results obtained in this study are close to kinematic viscosity values reported by Thahir et al. [22] which is 0.45 cSt. The fuel was obtained by pyrolysis of PP at a temperature of 600°C with oil purification using a bubble cap column distillation. Novarini et al. [23] in their research reported that the test of LDPE pyrolysis oil samples at a temperature of 300°C. The value of kinematic viscosity at a temperature of 40°C is almost close to the value obtained in this study, which is 0.42 cSt.

TABEL 3. Properties of oil product and fuel standard

Samples	Parameters			
	Kinematic viscosity at 40°C (cSt)	Density at 15°C (kg/m³)	Caloric value (MJ/Kg)	Flash point (°C)
A1	0.417	743	45.91	26,94
A2	0.439	746	45.98	27,22
A3	0.442	753	45.73	26,94
Gasoline standard	1.3-2.4	715-770	43.5-55.7	-
Diesel standard	2.0−4.5	815-870	45.6	52

Density test results are presented in Table 3. It was a parameter that determines fuel quality. Density can determine the consumption level of fuel in the engine. Density value must be in accordance with predetermined standards so that it cannot be too large or too small in value. Based on Table 3 shows that the density values produced by the three samples ranged from 743-753 kg/m^3. The highest density was obtained from the sample with a composition of 25% LDPE and 75% PP, which was 753 kg/m^3. This value is in accordance with gasoline quality standards on the market.

Calorific value is a number that states the amount of heat generated from combustion process of a fuel with air. Caloric value testing results are similar to Silvarrey and Phan [24] results which are in range of 44-48 MJ/kg. In addition, the caloric value results here is similar to the calorific value of testing petroleum fuels such as diesel or gasoline. The research results on pyrolysis oil products are often in the range of 33.6-53.4 MJ/kg. This value depends on the plastic polymer composition factor [25].

Flash point of a fuel indicates a safe limit against fire hazards during storage. It indicates the lowest temperature of fuel vapor mixture with air that allows combustion to occur. Flash point parameters are often used to characterize the hazard level of liquid fuels. Flash point that is too low will cause a small explosion that occurs before the fuel enters the combustion chamber or is called denotation. In addition, it can also increase the risk of fire risk during storage. Table 3 show that all the oil samples have a lower flash point than the standard diesel fuel. This study results flash point ranged from $26.94-27.22^oC$. The low flash point is due to volatile materials such as aromatic components contained in pyrolysis oil so that it requires safety in handling and transportation. The similar study results by Khan et al. (2016) used HDPE plastic waste as a fuel oil producer. Pyrolysis process in batches at a temperature of 475^oC without a catalyst. Resulting oil has a flash point of 15^oC. Saptoadi et al. [26] used polyethylene (PE), polypropylene (PP) and polystyrene (PS) plastic waste. Its process is carried out in batches at temperatures between 500-700^oC without a catalyst. The flash point test results of the three samples were at a value of 10^oC.

F. **Chemical Composition of Oil Product**

Table 4 shows GC-MS testing results from oil samples obtained from 100% LPDE waste pyrolysis results LPDE 100%, LDPE 25%: PP 75%, and LDPE 50%: PP 50%. Oil content identification results by GC-MS showed that the hydrocarbon compounds contained in the oil sample came from aliphatic, cyclic, and aromatic hydrocarbons.

The presence of compounds of cyclic and aromatic hydrocarbons is due to aromatization, oligomerization, and deoxygenation processes that occur on active side of the acidic zeolite catalyst [27]. Dawood and Miura [28] in their research reported that the conversion of plastics with straight chain monomers such as PE or PP into aromatic compounds and olefins increased with the use of modified zeolite catalysts.

Oil identification results by GC-MS showed that sample A1 with 100% LDPE composition was dominated by heptene and cyclohexane derivatives. Rizzarelli et al. [29] reported that the degradation mechanism in polyethylene polymers is possible through carbenium ion mechanism due to proton attack or hybrid ion abstraction through Lewis acid sites. Based on research by De Stafanis et al. [30] reported that catalytic degradation process of PE involves a carbenium ion mechanism through the addition of protons to C−C bonds or abstraction of hybrid ions with acidic sites to the PE molecule. The process is followed by step-by-step degradation into light hydrocarbons. Molecule degradation process with high molecular weight occurs on the outer surface of the catalyst. On the other hand, micropore catalysts can block the entry of compounds with a high weight so that it can lead to the formation of high carbon chain compounds as well as the formation of char.

In samples A1 and A2 which had a combination of LDPE and PP, an aromatic derivative of benzene (C_8H_{10}) was detected. The addition of PP polymer causes the potential for benzene-derived aromatic compounds found in oil products. Miandad et al. [18], reported the same thing that the use of activated zeolite catalyst in pyrolysis of PP compounds caused an increase in aromatic components. Acidic mesoporous catalysts cause the production of short chain hydrocarbons due to their relatively high cracking ability. Olefin intermediate compound produced from the catalytic pyrolysis then undergoes a further aromatization process in catalyst pores. Such process tends to produce hydrogen atoms which enhance aromatization process thereby increasing the aromatic compounds production [19].

Table 5 shows the identification results of compound content of pyrolysis oil classified according to carbon atom chain length. Table 5 above shows that the pyrolysis oil is composed of light fraction hydrocarbon compounds (C_4-C_{11}) and medium fraction hydrocarbon compounds ($C_{12}-C_{20}$). Light hydrocarbon fraction content in all samples was higher than medium hydrocarbon fraction. The hydrocarbon content of the light fraction was dominated by C_9, C_{10}, and C_{11} atomic chains, while the intermediate

fraction was dominated by hydrocarbons with C_{12} chains. Hydrocarbon content of pyrolysis oil light fraction has similarities to hydrocarbon content of gasoline which is composed of C_4-C_{11} carbon atoms. The presence of C_{12} hydrocarbon content indicates that the pyrolysis oil contains compounds similar to diesel fuel [31−32].

TABEL 4. GC-MS result of oil product

Samples	Retention time (min)	Abundance (%)	Chemical compound
A1	2.119	37.03	2,4-Dimethyl-1-heptene (C_9H_{18})
	2.23	8.90	1,3,5-trimethyl-Cyclohexane (C_9H_{18})
	2.389	8.59	Cyclohexane, 1,1,3,5-tetramethyl-trans ($C_{10}H_{20}$)
	4.039	4.54	2-Undecene, 4-methyl- ($C_{12}H_{24}$)
	2.304	4.29	Cyclohexene, 3,5,5-trimethyl ($C_9H_{16}O$)
	2.526	2.87	cis-3-Hexenyl pyruvate ($C_9H_{14}O_3$)
	4.086	2.72	2-Undecene, 4-methyl-($C_{12}H_{24}$)
	2.346	2.65	1,3-Heptadiene, 2,3-dimethyl- (C_9H_{16})
	3.171	2.35	4-Octene, 2,3,6-trimethyl- ($C_{11}H_{22}$)
	6.979	1.86	Cyclohexane, 1,1,3,5-tetramethyl-trans ($C_{10}H_{20}$)
A2	2.114	48.65	2,4-Dimethyl-1-heptene (C_9H_{18})
	2.383	9.32	Cyclohexane, 1,1,3,5-tetramethyl ($C_{10}H_{20}$)
	2.23	8.84	Cyclohexane, 1,3,5-trimethyl (C_9H_{18})
	2.304	7.02	Benzene, 1,3-dimethyl (C_8H_{10})
	2.352	5.04	Cyclopropane, 1-methyl-2-pentyl (C_9H_{18})
	2.521	2.24	cis-3-Hexenyl formate ($C_7H_{12}O_2$)
	2.447	1.87	Benzene, 1,3-dimethyl (C_8H_{10})
	3.097	1.87	1-Decene ($C_{10}H_{20}$)
	4.039	1.67	2-Undecene, 4-methyl ($C_{12}H_{24}$)
	3.171	1.52	4-Decene, 7-methyl ($C_{11}H_{22}$)
A3	2.114	45.42	2,4-Dimethyl-1-heptene (C_9H_{18})
	2.383	8.92	3,4,4-Trimethylcyclohexa ($C_9H_{16}O$)
	2.23	7.71	Cyclohexane, 1,3,5-trimethyl (C_9H_{18})
	2.299	5.93	1,3-Dimethylbenzene (C_8H_{10})
	4.034	3.20	Cyclohexane, 1,1,3,5-tetramethyl ($C_{10}H_{20}$)
	2.341	3.13	Cyclohexene, 3,5,5-trimethyl (C_9H_{16})
	2.521	2.59	Cis-3-Hexenyl Formate ($C_7H_{12}O_2$)
	3.166	1.96	2-Heptene, 2-methyl (C_8H_{16})
	4.086	1.80	5-Undecene, 4-methyl ($C_{12}H_{24}$)
	2.442	1.31	Cyclohexane, 1-propenyl (C_9H_{16})

TABEL 5.   Carbon range of pyrolysis oil compounds

Samples	Abundance of Carbon range (%)	
	C_4–C_{11}	C_{12}–C_{20}
A1	97.96	2.04
A2	96.56	3.44
A3	92.44	7.56

The results showed that plastic composition had an effect on the hydrocarbon content in the fuel oil. Sample A1 with LDPE content tends to produce the highest C_4–C_{11} chain hydrocarbons compared to other samples. The addition of PP to the LDPE sample gradually decreased the light hydrocarbon fraction but increased the percentage of the intermediate fraction composition. Generally, oil products produced from the catalytic pyrolysis process of LDPE and PP waste contain relatively abundant amounts of carbon and hydrogen.

IV.   CONCLUSION

The results showed that the yield of pyrolysis oil obtained in the composition of LPDE 100%, LDPE 75%: PP 25%, and LDPE 25%: PP 75% were 23.03%, 13.93%, and 8.18% respectively. The pyrolysis oil product obtained from the three samples has almost the same characteristics as gasoline fuel. This is evidenced by the density and calorific value in accordance with gasoline standards. However, the viscosity value does not meet the standards of gasoline and diesel. Pyrolysis of plastic waste with high LDPE content tends to produce oil with a high C4−C11 hydrocarbon chain composition. Based on the results of the study showed that catalytic pyrolysis with natural zeolite can be a promising technology for conversion of plastic waste into liquid oil.

V.   ACKNOWLEDGEMENT

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