Journal of Bio & Geo Material and Energy (BiGME)
Volume 2 No. 2, September 2022
P-ISSN: 2808-1560 E-ISSN: 2808-1404

Catalytic Cracking of Plastic Waste Polypropylene for Gasoline Production Using H-USY and Cr-USY

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Article info:

Submitted: August 2022
Accepted: August 2022
Published: September 2022

Abstract:
Fuel oil reserves are currently decreasing due to an imbalance between the increasing need for fuel consumption and the finding of new sources to fulfill these needs. On the other hand, plastic waste is also an environmental problem. Plastic waste is a synthetic polymer made from petroleum that is difficult to decompose in nature. An alternative route for waste must be applied to prevent a further environmental problem. Catalytic cracking is one alternative that converts plastic waste into liquid hydrocarbons. This research aims to determine the quantity of gasoline produced from the catalytic cracking process of polypropylene (PP) plastic waste using modified H-USY and Cr-USY catalysts. The sample used was plastic waste derived from bottled water packaging. The plastic waste was cut into small pieces, weighed, and then cracked thermally and catalytically with a catalyst: sample ratio 1:10. The results showed that catalytic cracking of PP waste using the H-USY catalyst produced 20.73% gasoline, while using the Cr-USY catalyst resulted in 14.4% and 13.68% gasoline using Cr-USY catalyst 0.1% and 0.3% respectively.

Keywords: Catalytic Cracking; Cr-USY; H-USY; Polypropylene.

1. Introduction

Fuel oil reserves, especially gasoline, are currently experiencing a decline. This happens because the need for fuel consumption is increasing due to the rapid development of various sectors, especially the industrial, household and transportation sectors, which use fuel as fuel. Meanwhile, the increasing need for fuel consumption is not balanced by an increase in the availability of sources to meet these needs, namely petroleum. On the other hand, plastic waste has also become a global environmental problem. This is because plastic waste, which is a synthetic polymer made from petroleum, is difficult to decompose in nature. However, the level of plastic use in everyday life is very high due to several advantages of plastic, including strength, lightness, and stability. Increasing the use of plastic will have an impact on increasing environmental pollution such as soil pollution (Kadir, 2012).

Petroleum is classified as a non-renewable natural resource. Sukarmin (2004) states that petroleum is formed from the decomposition of organic compounds originating from the bodies of organisms millions of years ago under high temperature and pressure, resulting in a complex mixture of hydrocarbons. The part of the mixture that is in the liquid phase is called petroleum, while the part that is in the gas phase is called natural gas. Because it is non-renewable, if petroleum reserves run out, it will take millions of years for petroleum to reform naturally.

Research on the catalytic cracking of plastic waste was also carried out by Trisunaryanti (2002), who conducted research on optimizing the time and catalyst/feed ratio in the catalytic cracking process of plastic waste fractions into gasoline fractions using a natural Cr-Zeolite catalyst. The sample used in this research was soft plastic from mineral drinking water packaging. From the catalytic cracking process carried out at a temperature of 450^{o}C using a Cr-Zeolite catalyst and plastic waste in a ratio of 1:3 with a total mass of 4 grams for 60 minutes, a gasoline fraction of 53.27% was produced. Meanwhile, thermal cracking (without a catalyst) produces a gasoline fraction of 13.93% with a cracking process duration of 90 minutes.

To be able to produce gasoline that meets specifications, has a high yield quantity, and a relatively fast manufacturing process, an appropriate catalyst is needed. Daniell, et al. (2001) stated that ultra stable zeolite Y (USY) is an industrial material in petroleum refining and is widely used as a catalytic cracking component. In line with this, Omegna, et al. (2003), also revealed that ultra stable zeolite Y (USY) is a cracking catalyst that is widely used in the petroleum refining industry, which is obtained by dealumination of zeolite HY at high temperature and pressure.

2. Research Methods

Material

Plastic waste was the bottles obtained from waste of bottled drinking water. Zeolite USY was obtained from Sigma Aldrich. The reactor for cracking was a semi batch stainless steel reactor as described previously (Prabasari et al., 2019).

Sample Preparation

Plastic bottle waste was collected, cleaned, dried, and cut into small pieces.

Thermal Cracking (Nazarudin, 2012)

The cracking process was carried out at a temperature of 350ºC using 20 grams samples for 30 minutes. Cracking is carried out by inserting the sample into the reactor, then heating to a temperature of 350°C. During the reaction, the reactor was supplied with nitrogen gas whose flow rate was maintained at 10 ml/minute. The reaction was carried out for 30 minutes (counting when the temperature in the reactor reached exactly 350°C). The resulting cracking liquid (OLP = Oil Liquid Product) is collected in the OLP reservoir. The OLP obtained is then distilled at the boiling point of gasoline (60ºC-120ºC). The weight of the product resulting from cracking and distillation is analyzed gravimetrically. Gravimetric analysis was carried out to determine the percentage yield of each OLP obtained in cracking and gasoline produced after distillation. The calculations used to find yield of OLP and gasoline are:

$$\text{OLP (\%)} = \frac{\text{OLP (g)}}{\text{Initial Weight (g)}}\ x\ 100\%$$

$$\text{Gasoline (\%)} = \frac{\text{Gasoline (g)}}{\text{OLP (g)}}\ x\ 100\%$$

Catalytic Cracking (Nazarudin, 2012)

The catalytic cracking process was carried out at a temperature of 350ºC using 2 grams of H-USY, Cr-USY 0.1% and Cr-USY 0.3% catalyst with a catalyst:sample ratio of 1:10 and a time of 30 minutes. Cracking is carried out by inserting the mixed sample and catalyst into the reactor in a ratio of 10:1 with a total mass of 22 grams, then heating to a temperature of 350°C. The rest procedure is the same as thermal cracking as described above.

Distillation

Distillation was carried out using vacuum distillation at 60ºC – 120ºC.

3. Result and Discussion

Thermal Cracking

Thermal cracking is carried out with the aim to obtain a control condition of cracking. By comparing thermal cracking with catalytic cracking, the effect of the catalyst can properly be determined. Thermal cracking of polypropylene plastic waste at 300ºC produces 60.4% oil liquid product (OLP). 10.51% of this OLP is gasoline (Table 1).

Table 1. Thermal cracking of polypropylene plastic waste

Cracking Product	Yield (%)
OLP	60.4
Gasoline	10.51

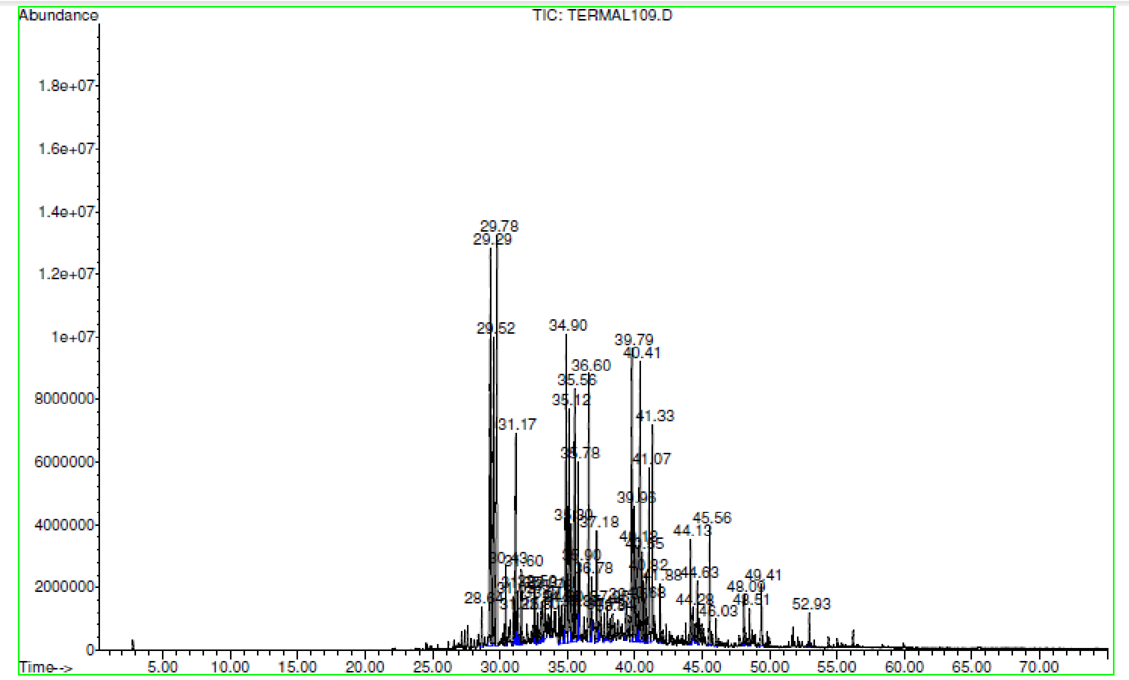

Figure 1. Chromatogram of distilled oil liquid product produced by thermal cracking of polypropylene plastic waste

The temperature used in GC-MS analysis is 40^{o}C-270^{o}C for 75 minutes. There are 50 peaks obtained in the analysis on distilled OLP thermal cracking which contains 119 possible compounds in the analysis of distilled OLP resulting from thermal cracking. It can be seen in Figure 1 that at minute 29.78 it has the highest peak. From the mass spectrometry analysis data obtained at 29.78 minutes has a large area (9.27%) and there are 2 possible compounds that appear, namely cyclodecanone ($C_{10}H_{18}O$) and 1,2-dimethyl-1 -methyl cyclohexane, ($C_{11}H_{24}$). GC-MS spectrum analysis of the peaks shown in the chromatogram shows that the gasoline components produced from thermal cracking predominantly contain hydrocarbon compounds from C7 to C12.

Catalytic Cracking

Catalytic cracking of polypropylene plastic waste produced brownish liquid as seen in Figure 2. After a vacuum distillation at 60^{o}C-120^{o}C, a clear yellow liquid was produced (Figure 2). When comparing thermal cracking with catalytic cracking, the USY catalyst has increased both OLP and gasoline yield (Table 1, 2). Among these catalysts, H-USY gives the highest yield of OLP and the highest percentage of gasoline in the OLP. Catalytic cracking of polypropylene using USY produced higher OLP compared to similar cracking using spent FCC which produced OLP below 40% (Harahap et al., 2022).

Figure 2. Oil liquid product (left) and distilled oil liquid product produced by catalytic cracking using H-USY

Table 2. Catalytic cracking of polypropylene plastic waste

Catalyst	OLP (%)	Gasoline (%)
H-USY	64.15	20.73
Cr-USY (0.1%)	63.06	14.4
Cr-USY (0.3%)	62.85	13.68

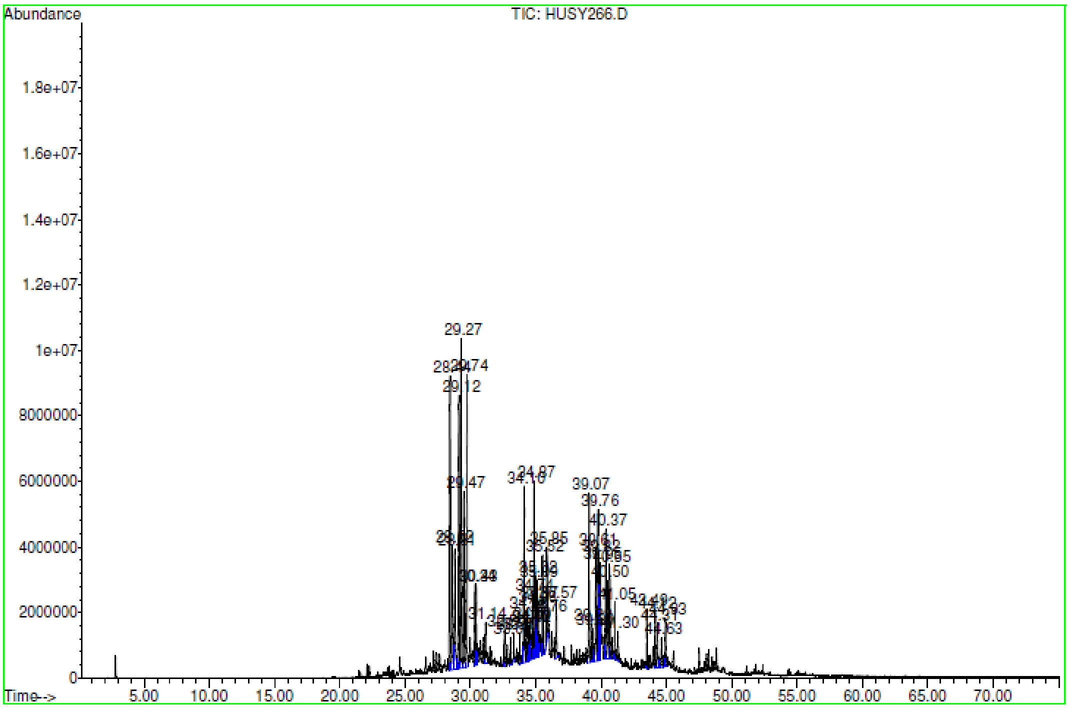

Figure 3. Chromatogram of oil liquid product produced by catalytic cracking of polypropylene plastic waste using H-USY

Analysis using GC-MS for distilled OLP produced by H-USY cracking products shows 37 peaks with 77 possible compounds contained in the distilled OLP. It can be seen in Figure 3 that at 29.27 minutes, there is a highest peak. At this peak, the largest % area (8.58%) denotes 3 possible compounds namely 4-Isopropyl-

1,3-cyclohexanedione ($C_9H_{14}O_2$), 1,1,3,5-tetramethyl-cis-cyclohexane ($C_{10}H_{20}$) and 1,3,5-trimethyl-cyclohexane (C_9H_{18}). GC-MS spectrum analysis of the peaks shown in the chromatogram in the image shows that the distilled OLP from H-USY cracking predominantly contains hydrocarbon compounds from C6 to C12 which is gasoline. The restrictions on hydrocarbon compounds that are categorized as gasoline are taken from research conducted by Rodiansono, et al (2006) on polypropylene hydrocracking which is limited to hydrocarbon compounds that contains C5 to C12 atoms.

Conclusion

Plastic waste polypropylene can be cracked into gasoline using H-USY with a better yield than using either 0.1% or 0.3% Cr-USY.

References

Damayanthi, R., Martini, R. 2007. *Proses Pembuatan Bahan Bakar Cair Dengan Memanfaatkan Limbah Ban Bekas Menggunakan Katalis Zeolit Y dan ZSM-5*. Semarang: Universitas Diponegoro.

Daniell, W., dkk. 2001. *An FTIR Study of the Surface Acidity of USY Zeolites: Comparison of CO, CD_3CN, and C_5H_5N Probe Molecules*. Germany: Ludwig-Maximilians-Universität.

Harahap PS, Syarifuddin H, Ulyarti, Nazarudin, N. 2022. Utilization of polypropylene (PP) plastic waste and empty palm fruit bunch for an alternative fuel. Indones. J. Fundam. Appl. Chem., 7(3), 143-147

Kadir. 2012. Kajian Pemanfaatan Sampah Plastik sebagai Sumber Bahan Bakar Cair. *DINAMIKA* Jurnal Ilmiah Teknik Mesin. Vol. 3(2): 223-228.

Nazarudin. 2012. *Catalytic cracking of plastic waste using nanoporous material*. [Disertasi] University College London

Omega. A. 2003. *Flexible Aluminum Coordination in Alumi Silicates-Structure of Zeolite H-USY and Amorphous Silica Alumina*. Zwitzerland: Institute for Chemical and Bioengineering-Swiss Federal Institute of Technology (ETH).

Prabasari IG, Sarip R, Rahmayani S, Nazarudin. 2019. Catalytic cracking of used cooking oil using cobalt-impregnated carbon catalysts. Makara Journal of Science. Vol 23 issue 3: 162-168

Rodiansono, Trisurnayanti, W., dan Triyono. (2006). Hidrorengkah Polipropilena Menjadi Fraksi Bensin Menggunakan Katalis Zeolit Alam Aktif (Z), Ni/Z, Ni/Z-γ-Al2O3. Journal of Alchemy.

Setiadi dan R. Mailisa Fitria. 2006. *Proses Katalitik Sintesis Hidrokarbon Fraksi Bensin dari Minyak Sawit Menggunakan Katalis B2O3/Zeolit.* Seminar Nasional MKICS, Universitas Indonesia, 26-27 Juni 2006. Jakarta: UI.

Sukarmin. 2004. *Hidrokarbon dan Minyak Bumi*. Bagian Proyek Pengembangan Kurikulum Pendidikan Menengah Kejuruan Direkrorat Jenderal Pendidikan Dasar dan Menengah Departemen Pendidikan Nasional. Surabaya.

Trisunaryanti, W. 2002. Optimasi Waktu dan Rasio Katalis/Umpan pada Proses Perengkahan Katalitik Fraksi Sampah Plastik Menjadi Fraksi Bensin Menggunakan Katalis Cr/Zeolit Alam. *Indonesian Journal of Chemistry* 2 (1). Yogyakarta : UGM.