



Converting polymeric mixture waste of a car breaker company to hydrocarbon by designed high performance co-pyrolysis system

Ali Khani^{a, b, *}, Shahram Mohammadi^b, Hamed Rasulzade^b

^aDepartment of Chemistry, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran

^bTaher shimi-e- Miyaneh Co., Miyaneh, Iran

ABSTRACT

Article history:

Received 1 July 2020

Received in revised form 30 July 2020

Accepted 10 August 2020

Available online 21 August 2020

Keywords:

Pyrolysis

Rotary kiln

Oil

Car scrapping

Waste produced from car breaker companies severely affects the environment. So far, the only way to manage this complex waste is to bury it. In this research, the waste converted to hydrocarbons and carbon black by co-pyrolysis process in the designed high performance co-pyrolysis system. The results showed that the as-obtained maximum yield of heavy oil and light hydrocarbon wax, carbon black and non-condensable gas can be listed as mass basis of 8, 34, 3, 40 and 15%, respectively. The ratio of 5 W/W% treated expanded perlite as catalyst to waste increased the amount of light hydrocarbons to 34 W/W%.

1. Introduction

Polymers have many applications in human life [1-3], from daily applications such as composite [4-6] to specialized and scientific uses [7-9]. For example, varieties of rubbers and plastics have been used in many parts of a car. However, the disposal of products such as cars at the end of their life still remains as an important environmental problem [10]. There are currently more than one million scrap cars in Iran that need to be broken. One of the products of car scrapping is polymeric waste. There is a market for the recycling of pure plastics, especially of polyethylene but also residues from the plastic manufacturing industry. The collection of plastics, the mechanical sorting of wastes and the utilization of used cars, however, give plastic wastes that are mixed or contaminated and are expensive to separate and recycle [11]. This polymeric scrap, including rubber and plastic pieces that are no longer recyclable and mixed with other types of waste such as oil, wood particles, etc., must be properly be buried in landfills. However, problems such as scarcity of landfills, high landfill costs, environmental pollution from wastes, etc. have led researchers to think of new and effective solutions. Thus, the recycling of waste polymers along with conversion into energy and recovery of valuable materials are

important from both economical and ecological point of views [12]. On the other, Petroleum fuels have a negative effect on the environmental deterioration and cause health risks by using unlimited sources. Thus, the waste material must be recycled to be used as fuel. The waste possess both a non-decomposed and nonbiodegradable material. Thus, waste polymers can cause terrible problems on the environment if they are not recycled properly [13]. When the waste are disposed at dumpsites, they can also cause serious human health, environmental and atmospheric problems.

Besides, in such places waste polymers keep destroying the ecology by bacteria growth, hosting mosquitoes, insects and pests through soil and groundwater [14]. Additionally, it causes high fire risk which cannot be easily extinguished and, also, the uncontrolled emissions of fire potential effect 11on the environment. The pyrolysis process can solve the mentioned problems. Furthermore, this process produces two valuable products; hydrocarbons as fuel and carbon black with many applications such as adsorbent, after conversion to carbon black. Activated carbon materials have a special place among the adsorbents, as for a long time they are known to be capable of adsorbing various pollutants such as organic compounds [15].

* Corresponding author. Tel.: +989143238611; e-mail: a.khani59@yahoo.com

The main purpose of the present article is to recycle and convert polymer waste resulting from the activities of a car breaker company called Fuka San'at Saba Co. located in Zanzan province, Iran into valuable products such as hydrocarbons and carbon black by designed high performance co-pyrolysis system.

2. Experimental

2.1. Materials

The polymeric waste sample obtained from the Fuka San'at Saba Co. and analyzed (Table 1). The expanded perlite was purchased from Goohar Sahand Co., Iran [16] and treated to use as catalyst. The experiments were repeated three times (variance (σ^2) = 0.01).

Table 1. The constructive composition of polymeric waste mixtures

Type of Material	W/W%	Mass (Kg)
Polymer	31	322.4
Soil	42	436.8
Wood	1	10.4
Metals	3	31.2
Water	23	239.2
Sample (summation)	100	1040.0

2.2. Methods

Detection and measurement of hydrocarbons were done by ASTM method in Iranian institute of research and development in chemical industries, Karaj, Iran. The designed high performance rotary kiln co-pyrolysis system was used to convert the wastes into hydrocarbons and carbon black (Figure 1).



Figure 1. The designed high performance rotary kiln co-pyrolysis system

The main parts of the system are as following: a) rotary kiln reactor (D=1.38 m, L=3 m, Thickness= 15 mm) with catalyst room, b) gas- liquid separator, c) special filter to redirect water to another direction, d) conical filter with

bypass to recycle unbroken and heavy hydrocarbons, e) water cooling system and f) reservoir tank. Reactor is the main component of the system. The wastes are heated and molten at the rotary kiln reactor. The capacity of reactor is roughly 1.5 tonnes. There is a heating furnace unit under the reactor, which burns natural gas (urban gas) to run the system and after a while, a certain non-condensable gas is burned in the furnace instead of natural gas usage. The rotation speed can be varied between 0.2 rpm and 0.4 rpm and the optimum temperature is 380 °C.

The heavy and light oils are products obtained through a rotary kiln reactor pyrolysis at an optimum temperature of 380 °C and 8 °C.min⁻¹ heating rate. In a study, similar results were reported [17]. The as-obtained maximum yield of heavy oil and light hydrocarbon (Figure 2), wax, carbon black and non-condensable gas can be listed as mass basis of 8, 34, 3, 40 and 15%, respectively.



Figure 2. Light hydrocarbon appearance

The results showed that in terms of mass, the main product is light hydrocarbon (LH). Some properties of LH were summarized in Table 2.

Table 2. Some properties of the produced light hydrocarbon

Property	Unit	Value
Density (in 15.6 °C)	g.cm ⁻³	0.81
Flash point	°C	Free
Total sulfur	ppm	4566
Mercaptan	ppm	64
Pour point	°C	<-30

3. Results and Discussion

The pyrolysis conditions are affected by the heating rate (the final pyrolysis temperature), residence time (explosion duration) and presence/absence of the

catalyst that could change the mass percentage of the products.

3.1. Effect of the heating rate on light hydrocarbon percentage (LH%)

Hydrocarbons are evaporated and liquefied at different heating rates. Furthermore, the final temperature affects the amount of productions. For this purpose, the experiments were carried out with heating rate varying from 2-8 °C.min⁻¹. The results are given in Table 3.

Table 3. Effect of the heating rate (HR) on mass percentage of the LH%

HR (°C.min ⁻¹)	Final Temperature (°C)	Yield (W/W%)
4	350	29
6	366	31
8	380	34
10	401	33

The pyrolysis temperature must be high enough to thermally degrade the polymers; however, higher temperatures and long gas residence times in the reactor hot zone can volatilize the oil to gas [18]. Increasing the heating rate increases the degradation rate, and also affects the temperature at which maximum volatilization starts and stops [19]. Higher heating rates lead to higher temperatures, which can lead to more secondary reactions, which can produce more gas-phase [20] and light hydrocarbons products.

3.2. Effect of the residence times on light hydrocarbon percentage (LH%)

Pyrolysis time is related to particle size: in general, larger particles require longer residence times to achieve the same degree of conversion [19]. Pyrolysis time is also linked to heating rate, with lower heating rates requiring longer pyrolysis times. The optimal residence time was about 12 h. No significant change in the amount of the main product (LH%) was observed after this time. During residence of less than 12 h, the amount of products such as heavy oil and wax increased.

3.3. Effect of the Catalyst on light hydrocarbon percentage (LH%)

Catalysts can be used to improve pyrolysis rate, oil quality, oil yield, and yields of compounds such as aromatics for chemical production [21]. The effect of catalyst (treated expanded perlite) dosage was examined at different catalyst/waste ratio ranging from 0 to 15 W/W%. The results were summarized in Table 4.

Table 4. Effect of the catalyst dosage on mass percentage of the LH%

Catalyst dosage (W/W%)	Mass of catalyst (Kg)	Yield (W/W%)
0	0	31
5	52	34
10	104	28
15	156	28

Ates, et al. also boosted both oil yield and oil aromatic content using 10 W/W% activated alumina [22]. In addition to increasing the reaction rate, the catalyst breaks down polymer molecules more and more into smaller molecules (light hydrocarbon and non-condensable gas such as methane).

4. Conclusion

By co-pyrolysis process in the designed high performance co-pyrolysis system, the polymeric scrap, including rubber and plastic pieces that are no longer recyclable and mixed with other types of waste such as oil, wood particles, etc., was converted to hydrocarbons and carbon black with appropriate efficiency. The heavy and light oils are products obtained through a rotary kiln reactor pyrolysis at an optimum temperature of 380 °C and 8 °C.min⁻¹ heating rate. The results showed that in terms of mass, the main product is light hydrocarbon. Higher heating rates lead to higher temperatures, which can lead to more secondary reactions, which can produce more light hydrocarbons products. The optimal residence time was about 12 h and the used treated expanded perlite as catalyst breaks down polymer molecules more and more light hydrocarbon.

Acknowledgements

The authors would like to express their gratitude to Mr. J. Karimi, CEO of Fuka San'at Saba Co., for his financial support and assistance.

References

- [1] S. Pirsra, P. Abdolsattari, S. J. Peighamardoust, S. H. Fasihnia and S. H. Peighamardoust, Investigating microbial properties of traditional Iranian white cheese packed in active LDPE films incorporating metallic and organoclay nanoparticles. *Chemical Review and Letters*, 3(2020) 68-174.
- [2] S. Pirsra, F. Mohtarami and S. Kalantari, Preparation of biodegradable composite starch/tragacanth gum/Nanoclay film and study of its physicochemical and mechanical properties. *Chemical Review and Letters*, 3 (2020) 98-103.
- [3] S. Pirsra and K. Aghbolagh Sharifi, A review of the applications of bioproteins in the preparation of biodegradable films and polymers, *Journal of Chemistry Letters*, 1 (2020) 47-58.

- [4] I. Karimi Sani, S. Pirsá and Ş. Tađı, Preparation of chitosan/zinc oxide/Melissa officinalis essential oil nano-composite film and evaluation of physical, mechanical and antimicrobial properties by response surface method. *Polymer Testing*, 79 (2019), Accepted Manuscript.
- [5] M. Pirouzifard, R. Ashrafi Yorghanlu, S. Pirsá, Production of active film based on potato starch containing Zedo gum and essential oil of *Salvia officinalis* and study of physical, mechanical, and antioxidant properties. *Journal of Thermoplastic Composite Materials*, 33(2019) 915-937.
- [6] S. Pirsá, T. Shamusí, Intelligent and active packaging of chicken thigh meat by conducting nano structure cellulose-polypyrrole-ZnO film. *Materials Science and Engineering: C*, 102 (2019) 798-809.
- [7] H. Almasi, B. Ghanbarzadeh, J. Dehghannia, S. Pirsá and M. Zandi, Heterogeneous modification of softwoods cellulose nanofibers with oleic acid: Effect of reaction time and oleic acid concentration. *Fibers and Polymers*, 16(2015)1715-1722.
- [8] S. Pirsá, Biodegradable film based on pectin/Nano-clay/methylene blue: Structural and physical properties and sensing ability for measurement of vitamin C. *International Journal of Biological Macromolecules*, *Macromolecules*, 163 (2020) 666-675.
- [9] S. Pirsá, E. Farshchi and L. Roufegarinejad, Antioxidant/Antimicrobial Film Based on Carboxymethyl Cellulose/Gelatin/TiO₂-Ag Nano-Composite. *Journal of Polymers and the Environment*, (2020) 1-10.
- [10] E. Aylon, A. Fernáandez-Colino, M. V. Navarro, R. Murillo, T. Garcí'a, and A. M. Mastral, Waste Tire Pyrolysis: Comparison between Fixed Bed Reactor and Moving Bed Reactor. *Ind. Eng. Chem. Res.* 47 (2008) 4029-4033.
- [11] W. Kaminsky, Recycling of polymers by pyrolysis. *Journal de Physique IV Colloque*, 03 (1993)1543-552.
- [12] J. Haydary, L. Jelemensky, L. Gasparovic and J. Markos, Influence of particle size and kinetic parameters on tyre pyrolysis. *J Anal Appl Pyrol.* 97 (2012) 73-79.
- [13] A. Ayanoglu and R. Yumrutas, Rotary kiln and batch pyrolysis of waste tire to produce gasoline and diesel like fuels, *Energy Conversion and Management*. 111 (2016) 261-270.
- [14] S. Poyraz, Z. Liu, Y. Liu and X. Zhang, Devulcanization of scrap ground tire rubber and successive carbon nanotube growth by microwave irradiation. *Curr Org Chem.*17 (2013) 2243-2248.
- [15] N. Daneshvar, S. Aber, A. Khani and A.R. Khataee, Study of imidaclopride removal from aqueous solution by adsorption onto granular activated carbon using an on-line spectrophotometric analysis system. *Journal of Hazardous Materials*. 144 (2007) 47-51.
- [16] A. Khani and B. Pezeshki, Easy simultaneous synthesis-immobilization of nanosized CuO-ZnO on perlite as a photocatalyst for degradation of acid orange 7 from aqueous solution in the presence of visible light, *Desalination and Water Treatment*, 57 (2016) 7047-7053.
- [17] M. Banar, V. Akyıldız, A. Özkan, Z. Çokaygil and Ö. Onay, Characterization of pyrolytic oil obtained from pyrolysis of TDF (tire derived fuel). *Energy Convers Manage.* 62 (2012) 22-30.
- [18] L. Gašparovič, L. Šugár, L. Jelemenský and J. Markoš, Catalytic gasification of pyrolytic oil from tire pyrolysis process. *Chem Pap.* 67(2013) 1504-1513.
- [19] J.D. Martínez, N. Puy, R. Murillo, T. Garcí'a, M.V. Navarro, A.M., Mastral Waste tire pyrolysis-a review. Excellent review of tire pyrolysis studies concerning factors impacting distribution of gas, liquid, and solid phase pyrolysis products and their physical/chemical properties. *Renew Sust Energ Rev.* 23 (2013)179-213.
- [20] A. Alsaleh and M.L. Sattler, Waste Tire Pyrolysis: Influential Parameters and Product Properties, *Curr Sustainable Renewable Energy Rep.* 1(2014)129-135.
- [21] Y.Kar, Catalytic pyrolysis of car tire waste using expanded perlite. *Waste Manag.* 31 (2011)1772-82.
- [22] F. Ates, A.E. Pütün, and E. Pütün Fixed bed pyrolysis of *Euphorbia rigida* with different catalysts. *Energ Convers Manag.* 46 (2005) 421-32.