

PRODUCTION OF BOILER AND FURNACE FUELS FROM DOMESTIC WASTES (POLYETHYLENE ITEMS)

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Received July 17, 2018; Accepted October 19, 2018

Abstract

The results of the thermal destruction of solid domestic waste (which are polyethylene items) were presented for batch-type laboratory equipment. According to the modern requirements of EU for the amount of sulphur in fuel and boiler fuels, polyethylene items are a valuable source for production of these fuels.

During atmospheric heating of the raw material in reactor the intensive destruction of polyethylene can be observed in the range of temperature 560–580 K. It has been defined the composition of products of polyethylene thermal destruction: 95 % (mass.) of liquid hydrocarbons, 4,5 % (mass.) of light hydrocarbon gases and 0,5 % (mass.) of coke. Fractionation of liquid hydrocarbons allows to separate 15 % (mass) of fraction 340-488 K, 14 % of fraction 406-518 K, 43 % of fraction 438-546 K and 27 % of residue (>623°C fractions).

Liquid products can be applied for production of boiler and furnace fuels independently and in a mixture with the petroleum processing products in different ratio.

Keywords: polyethylene items; thermal destruction; reactor; boiler fuel; fractionation, residue; aromatic hydrocarbons.

1. Introduction

In a condition of strong development of technosphere, we have a problem of accumulation of municipal, industrial and other waste. The territories which are considered to be applied for utilization of waste must be withdrawn from the agricultural fund for no less than 100 years. Nevertheless, technological processing of waste is an important income item in many countries of EU and can be applied for the production of electrical energy and different construction materials.

2. Publication analysis

Nowadays polyethylene items are the most common source of domestic waste in a world, and the most common way for their utilization are landfilling and burning with the production of electrical energy ^[1]. However, implementation of these ways doesn't solve the problem of environmental pollution because the burning of polymers leads to the formation of a huge amount of gaseous and solid waste.

The most common way of utilization is crushing and granulation of polyethylene waste for the further production of packet, film, etc. ^[2-3] and production of complex technical items through the die-casting ^[4].

There is a way of production of synthetic fuel through the dissolving of solid polyethylene briquettes with the heating of solution up to 380-400 K with the further supply to the burners of an internal combustion system ^[5]. To increase the strength of briquettes, different authors propose to dissolve 8-14 % mass of polyethylene in the liquid hydrocarbon fraction with the further cooling and crystallization of the hardener ^[6]. Authors of ^[7] have performed the tech-

nology of production of composite solid fuel by the combined processing which includes briquetting of the mixture (5-10% (mass.) of polyethylene, 3-5% (mass.) of waste oil and up to 90% (mass.) of coal or coke dust. There is a technology of carbonization of solid domestic waste at 720 K in an ultrahigh-frequency microwave radiation field which is aimed at obtaining of 12.9 % (mass) gaseous products, 48.5 % (mass.) of fuel oil 38.6 % (mass.) of solid residue [8].

There is also a well-known way of processing of polymer materials through the catalytic thermal decomposition in the alkyl-benzene. Temperature is 540-700K and pressure is 6 MPa. The disadvantage of the process is the application of expensive rare-earth material for the catalyst [9].

There was proposed the catalytic destruction of polyethylene at 620–670K at atmospheric pressure. The hydrocarbon mixture that was obtained in this way can be applied as a raw material for the motor fuels or at petrochemical plants [10]. Due to the destruction of polyethylene in the presence of synthetic catalyst, we can obtain a fraction which is similar to gasoline [11]. Authors of [12] described the production of motor fuel components which contain a significant part of iso-structure hydrocarbons that increase the antidetonation properties of this fuel.

Boiler and furnace fuel are widely used along with the motor in the industry and domestic economy that's why the production of the boiler and furnace fuel should be carefully studied.

3. The purpose and goal of the research

Current trends in the EU according to the application of liquid boiler fuel with a low amount of sulfur, require the complete desulfurization of raw material. From the one side, it makes the application of condensing boils easier and decreases the harmful emission, from the other side – it makes the fuel more expensive. The most rational solution is the production of the boiler and furnace fuel which meet the EU standards and decrease the environmental impact of the accumulated waste.

4. Experimental part

Exhausted polyethylene items are processed for obtaining of liquid components of the boiler and furnace fuel at the laboratory unit (Fig. 1). Sorted and crushed polyethylene (size of particles is 2×2 mm) was uploaded into the reactor 1. The raw material was heated up by the electric oven 2. Pressure and temperature were controlled by pressure gauge 3 and two thermocouples 4.

The shut-off valve was installed to provide the high pressure if it is necessary. Thermal destruction products get to the condensing fridge 6 through the shut-off valve 5. Non-condensed gases can be removed from the unit through the condensing fridge 6.

If it is necessary to keep the temperature of the coolant (oil) in condensing fridge 6 between 546-566 K, the electrical heating can be provided. That's why oil is applied as a coolant in fridge 6 instead of water. Condensed liquid products get to the storage after thermal destruction.

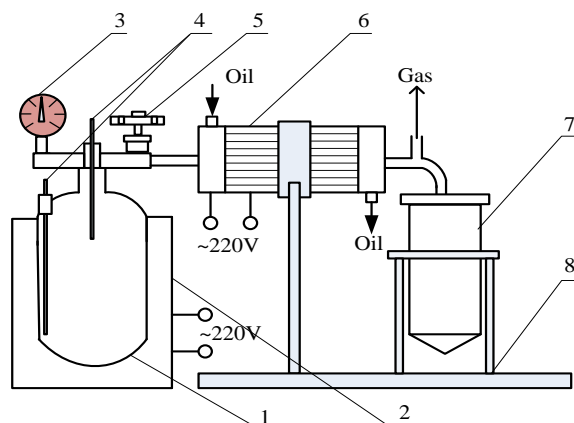


Fig 1. Laboratory unit for polyethylene destruction: 1 – reactor; 2 – oven; 3 – pressure gauge; 4 – thermocouples; 5 – shut-off valve; 6 – condensing fridge; 7 – storage for the liquid product; 8 – tray

During the atmospheric heating of polyethylene, the intensive thermal destruction of polyethylene is performed at 560- 580 K (zone II). Before (zone I) and after (zone III) this area speed of thermal destruction is constant (Fig. 2)

The speed of thermal destruction (Fig. 3) has been also studied. The speed increases at 560 K, passes through the maximum at 578 K and rapidly decreases at 588 K which correlates to the zone of intensive thermal destruction.

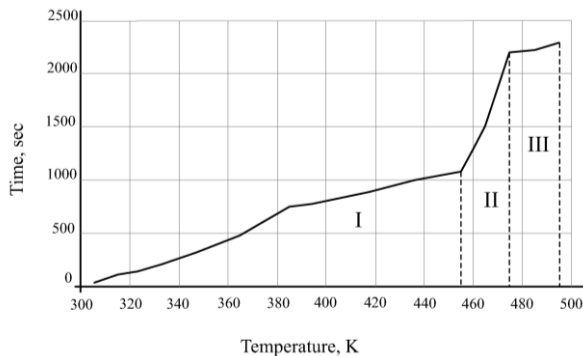


Fig.2. Temperature variation through time

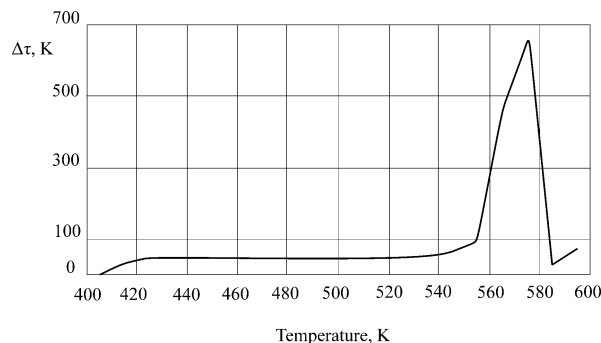


Fig 3. Research of thermal destruction speed

Liquid products of destruction were studied in the laboratory by the standardized methods for determining the physico-chemical quality indices. Gasoline and diesel fractions were studied by the chromatograph to determine their chemical composition. The liquid residue of thermal polyethylene destruction was studied by IR spectroscopy.

5. Results and discussion.

Fractional composition of thermal decomposition liquid products was studied according to the standard ASTM D86 (Fig. 4). Fraction №1 (conditionally gasoline) was taken at 453 K, fraction № 2 (conditionally kerosene)–453-513 K and fraction №3 (conditional diesel)–513-623 K.

Light hydrocarbon gases yield was about 4,5 % (mass.), coke yield – about 0,5% (mass.). Results of a laboratory study of narrow fractions have been performed in table 1. Results of a chromatographic study of gasoline and diesel fraction have been performed at fig. 5 and 6.

The summary content of aromatic hydrocarbons in gasoline fraction is 7.48 % (mass) and 0.84 % of benzene, which completely correlates to the current requirements. In diesel fraction high-molecular aromatic hydrocarbons that cause formation of soot in fire chambers and also cause the formation of harmful carcinogenic substances in the gaseous burning are completely absent.

The liquid residue of destructive polyethylene processing was studied by IR spectroscopy which has defined normal paraffin mainly (wave number 2851 – 2954 cm⁻¹). The content of other aromatic hydrocarbons (wave number 1641 cm⁻¹) is insignificant.

Table 1. Results of laboratory research of narrow fractions after the thermal destruction

№	Name of indices	Name of a narrow fraction		
		Gasoline	Kerosene	Diesel
1.	Density, kg per m ³	732	789	807
2.	Fractional composition, yield, % (vol.) at temperature, °C	IBP – 67 10 – 80 50 – 118 90 – 187 FBP – 215	IBP – 133 25-195 FBP – 245	IBP – 165 50 – 268 96 – 331 FBP – 348
3.	Pour point, K	-	255	263
4.	Flash point, K	-	309	348
5.	Kinematic viscosity, mm ² per second at 313 K	-	2.36	2.68
6.	Sulfur content, % (mass.)	0	0	0

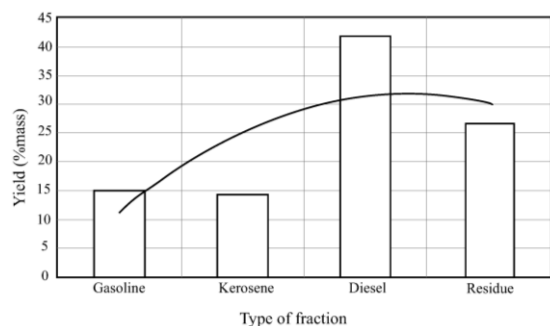


Fig. 4. Fractional composition of thermal decomposition liquid products

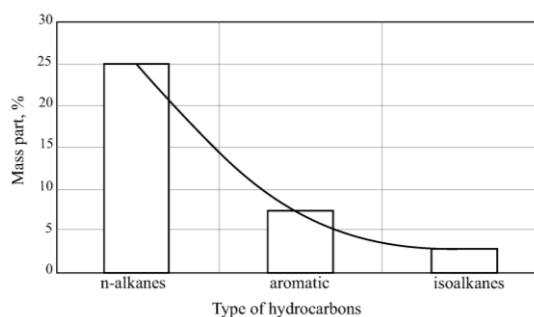


Fig. 5 The composition of the gasoline fraction

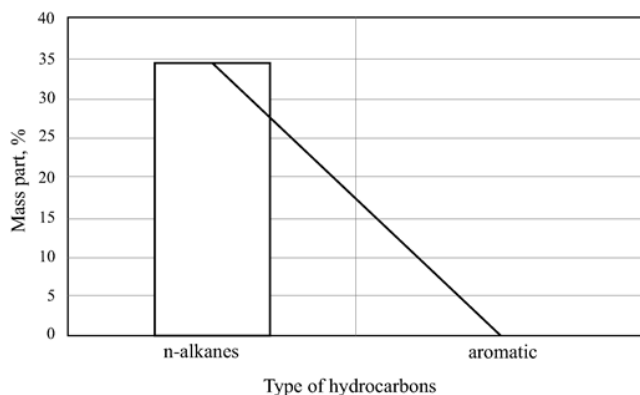


Fig. 6. The composition of diesel fraction

5. Conclusion

The provided research has shown the possibility of application of domestic polyethylene waste as a valuable source for production of liquid hydrocarbons by thermal destruction (total output of liquid products is 95% (mass.) of raw material). These products can be applied for production of boiler and furnace fuel both independently and in a mixture with the petroleum processing products. The components percentage is calculated according to the physical and chemical indices of fuel.

It should be mentioned that provided research is only the first step for the industrial implementation of thermal destruction of polyethylene and this process has to be studied in the direction of raw material preparation and compounding of commodity fuel according to the technical and ecological requirements.

References

- [1] Denisenko TM. Doslidzhennya suchasnih tehnologiy pererobki plastikovih virobiv. Visnik chernigivskogo derzhavnogo tehnologichnogo universitetu. 2014; 1 (71): 55–64.
- [2] Kartovenko VM, Makarov YuV. Rus. Patent 2537916, 2011.
- [3] Ischenko VA. Doslidzhennya tsiklu utilizatsiyi plastikovih virobiv. Visnik natsionalnogo tehnichnogo universitetu Ukrayini «Kiyivskiy politehnichniy Institut». Seriya «Himichna Inzheneriya, ekologiya ta resursozberezhennya». 2012; 1: 77–79.
- [4] Mikulonok IO. Obladnannya i protsesi pererobki termoplastichnih materialiv z vikoristannyam vtorinnoyi sirovini: monografiya. IVTs "Vidavnitstvo «Politehnika". 2009; 265 p.
- [5] Gavrilyuk YuM. Analiz tehnologiyi vigotovlennya virobiv iz polietilenu metodom litva pid tiskom. Visnik KNU Imeni Mihayla Ostrogradskogo. 2010; 6 (65): 89–91.
- [6] Shleyfer AA, Shleyfer AA. Rus Patent 2035493, 1995.

- [7] Ramazanov KR. Kompozitnoe toplivo iz othodov. Novyy universitet. 2016; 1 (47): 9-11.
- [8] Gunich SV. Tehnologiya mikrovolnovoy karbonizatsii organicheskikh komponentov tverdyih byitovyyih othodov. Izvestiya VUZov. Prikladnaya himiya i biotekhnologiya. 2011; 1: 137-139.
- [9] Platonov VV. Rus. Patent 2110535, 1998.
- [10] Galiahmetov RN, Sudakova OM. Sposob polucheniya topliva iz othodov polietilena. Pererabotka uglevodorodnogo syirya, 2016; 2: 249 - 250.
- [11] Furda LV. Kataliticheskaya destruktsiya polietilena v prisutstvii sinteticheskikh alyumosilikat. Zhurnal prikladnoy himii. 2008; 81(9): 1555-1558.
- [12] Poluchenie motornogo topliva iz othodov polimerov. Uspehi himii i himicheskoy tekhnologii, 6: 44-49.
- [13] Sharma BK, Moser BR, Vermillion KE, Doll KM, Rajagopalan N. Production, characterization and fuel properties of alternative diesel fuel from pyrolysis of waste plastic grocery bags. Fuel Processing Technology, 2014; 122: 79-90.
- [14] Syamsiro M, Saptoadi H, Norsujianto T, Noviasri P, Cheng S, Alimuddin Z, Yoshikawa K. Fuel Oil Production from Municipal Plastic Wastes in Sequential Pyrolysis and Catalytic Reforming Reactors. Energy Procedia., 2014; 47: 180-188.

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