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Technology for Producing Components of Technological and Boiler Fuels from Polymer Raw Materials

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Abstract

The article presents a schematic diagram of obtaining the components of technological and boiler fuels from polymer raw materials represented by materials from low and high pressure polyethylene, polypropylene and polystyrene. This scheme is based on the process of non-catalytic thermal destruction of raw materials in a batch reactor and consists of a section for preparation of raw materials, a section for thermal destruction as well as the fractionation of the resulting products.
The given scheme on an industrial scale, depending on the properties of the raw material, makes it possible to obtain 10-20% (mass) of the fraction - 200°C, 30-50% (mass) of the 200-360°C fraction and 20-30% (mass.) fractions (> 360°C). Among the by-products, 3.0-5.0% (mass) light hydrocarbon gases (0.5-1.0 mass %) and the coke residue are formed.
According to their properties, the obtained liquid products can be used as components for the production of process and a boiler fuel or as additives to improve the low-temperature properties of commercial fuels.

Keywords: *Polymeric materials; Secondary raw materials; Thermal destruction; Reactor; Fuel; Fractionation, Component; Properties.*

1. Introduction

In present-day conditions of developing science and technology, there is an annual rapid growth in the consumption of various types of fuel: motor, technological and boiler houses. At the same time, more and more stringent requirements are imposed on them regarding their quality and the effect of their combustion products on the human body and the environment. It is possible to comply with these requirements in the production of fuel, on the one hand, by modernizing the technological process (using new advanced technologies and materials), and on the other hand, by compounding the fuel with various components that can simplify the procedure for its use and improve its performance and environmental disposal.

2. Research objective

The compounding route is the most promising, especially for such countries such as Ukraine, which is mainly due to the lack of high-quality crude oil and the impossibility of complete modernization of the existing production. But at the same time, a number of specific requirements are also imposed on the components that are planned to be used in commercial fuels: they must provide industrial volumes of compounded fuel production; they must be both cheap and technological; and they must significantly improve the properties of the compounded fuel and they should not be classified as a hazardous substance (hazard class III or IV).

The cheapest raw material for the production of fuel components today is recycled materials, in particular polymers (polyethylene, polypropylene and polystyrene), which, due to their resistance to biological degradation in natural conditions, are subject to mandatory disposal [1-2].

Given the potential for the positive properties of recycled polymeric materials (high molecular weight, absence of sulfur, melting point, water resistance and resistance to chemical reagents), they can be used as a raw material or component in the production of various types of petroleum products. Thus, solid secondary polyethylene of high and low pressure was proposed to be used as the main raw material [3] or a dispersed phase of greases [4] and also as an additive to commercial greases in order to improve their rheological properties [5] and water resistance [6]. There are works where it is proposed to use polyethylene and polypropylene polymer additives to modify the properties of petroleum bitumen. That is, to increase their softening temperature, elasticity and low-temperature properties [7-8]. However, the bulk of work on the processing of solid polymeric materials is devoted to obtaining from them motor fuel (gasoline and diesel fuel) and its components [9-14].

At the same time, there is completely no information on obtaining components for such types of fuel as technological and boiler fuel, which are widely used today in industry and municipal services. Note that for their production, unlike motor fuels, there is no need to use complex technological equipment, high pressure and temperature, as well as the use of catalysts, which, in turn, affects the growth of the cost of the final product.

3. Results and discussions

To implement the process of obtaining components of technological and boiler fuel, relying on the properties of raw materials, in particular the temperature of thermal destruction of polymers, which is in the range of 280-380°C, it is sufficient to use a reactor-type apparatus that operates in the temperature range up to 400°C and pressure up to 0.25 MPa and a column of equipment for fractionation of the obtained products [15]. In this regard, we will propose a schematic diagram of the production of process and boiler fuel components (see Fig. 1), which, based on economic feasibility (location of communications, equipment, systems for cleaning harmful emissions), can be implemented at the industrial site of an oil refinery. The main technological parameters of the installation are presented in Table. 1 and the characteristics of the obtained products are in Table. 2.

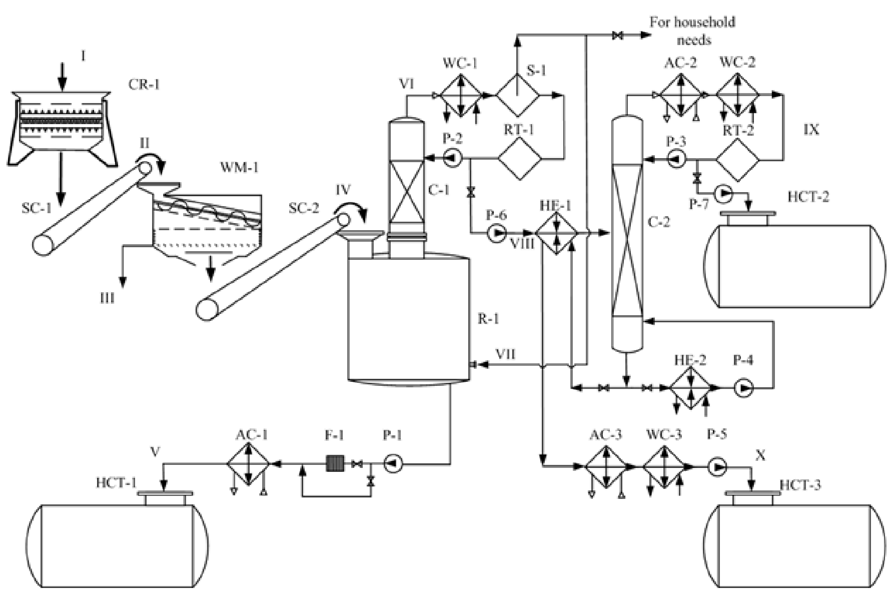

Figure 1. A schematic diagram of obtaining components of technological and boiler fuel: I - polymeric raw materials; II - crushed raw materials; III - wastewater; IV - washed and dried raw materials; V - fraction (> 360°C); VI - not stable fraction (b.p.- 360°C); VII - hydrocarbon gases; VIII - stable fraction (b.p. - 360°C); IX - fraction (b.p.-200°C); X - fraction (200-360°C)

According to the scheme shown in Fig. 1. preliminarily sorted polymer raw material stream I, in order to reduce the overall dimensions of the equipment and intensify further technological processes, is crushed in a CR-1 rotary crusher to a particle size of no more than 2 × 2 mm. The crushed polymer stream II enters the SC-1 belt conveyor and then for washing and drying into the WM-1 apparatus where various contaminants are removed from the crushed polymer raw materials, which, together with the waste water, stream III, are fed into the purification system, and then into a closed water cycle for use in the technological equipment of the installation. The washed and dried raw material stream IV enters the SC-2 belt conveyor, and then into the R-1 reactor type apparatus, where it undergoes a thermal destruction.

Table 1. Technological parameters of the installation

Item, dimension	Value
Crude capacity, kg/h.	50
Unit operation mode	Periodic
Fuel flow rate, kg/h.	3.0
Unit dimensions, L×B×H, m	9.0×6.0×8.0
Mass, kg	13000
Destruction reactor:	
- P, MPa	0.1 ÷ 0.25
- t, °C	280 ÷ 400
- L, m	0.5-1.5
Fractionation columns:	
C-1:	
- P, MPa	0.05 ÷ 0.35
- t, °C	250 ÷ 280
C-2:	
- P, MPa	0.05 ÷ 0.20
- top temperature, °C	140 ÷ 180
- bottom temperature, °C	300 ÷ 350
Commercial tanks:	
HCT -1	
- t, °C	60÷80
- L, m	0.9÷1.5
HCT -2	
- t, °C	25÷30
- L, m	1.2÷2.2
HCT -3	
- t, °C	35÷45
- L, m	1.5÷2.5
Filter pressure drop, MPa	0.06-0.09

The reactor is a vertical apparatus with a screw placed inside for mixing the raw material, in order to warm it up evenly and prevent it from being coked to a flame tube with a burner through which the fuel combustion products pass, heating the polymer raw material. After that, the products of fuel combustion enter the chimney and, after cleaning from harmful elements in the catalyst filter, are released into the atmosphere. The reaction temperature is kept constant by adjusting the burner power. To ensure a stable operation in the reactor, instrumentation means are provided, connected with the general automated process control system.

In the process of thermal destruction, the unstable fraction (b.p. - 360°C), flow VI, evaporates and flows upward of the column C-1, and the heavier fraction (> 360°C), flow V, upon reaching the required level in the reactor R-1, pump P-1 is pumped through a mesh filter F-1, air cooler AC-1 and enters the horizontal commodity tank HCT-1, equipped with the level, temperature and pressure alarms.

To cool the pump P-1, water is used, which circulates through certain taps, and to protect it from unacceptable excess pressure, in the event of possible closing of the taps and blocking of the pipeline, a safety valve is provided that dumps the fraction (> 360 °C) flow V to the pump suction.

Table 2. Characteristics of the received products

Parameter name	Numerical values of indicators for commodity fractions		
	IX	X	V
Boiling range, °C	50 ÷ 200	200 ÷ 300	>360
State of aggregation at 20 ° C	liquid	liquid	solid
Density at 20 ° C, kg/m^3	720 ÷ 740	800 ÷ 815	830 ÷ 890
Kinematic viscosity at 20°C, mm^2/s	0.7÷1.2	3.4 ÷ 4.2	-
Mass fraction of water, %		None	
Corrosive action on metals at 60°C, - Copper - Steel		None	
Chilling point, °C	~ - 65 ÷- 70	-20 ÷ -45	50 ÷ 65

The F-1 filter is designed to clean the fraction from mechanical impurities before feeding it to HCT -1. The filter is equipped with a differential pressure gauge to control the differential pressure across the filtration surface.

Column C-1 is designed to capture vapors of the fraction (> 360°C), which rises upward with the vapors of the unstable fraction (b.p. - 360°C). Column C-1 is a vertical apparatus with a regular packing and irrigation devices that ensure uniform distribution of reflux over the contact surface.

From the top of the column C-1, an unstable fraction (b.p. - 360°C) flow VI is removed and, passing through the water cooling apparatus WC -1, separator S-1, it is stabilized and fed into the reflex tank RT-1. Then it is divided into two parts: the first, with the help of the P-2 pump, returns to the C-1 column as cold reflux, the second, by the P-6 pump, is fed through the HE-1 heat exchanger, where it is heated by the heat that the fraction (200-360°C) stream X enters the column C-2. Hydrocarbon gases of the stream VII, which are released in the separator S-1, are fed for combustion to the burner of the R-1 reactor to maintain a constant temperature of the process or are used to obtain heat energy for the household needs of the enterprise.

In column C-2, a stable fraction (b.p.- 360°C) stream VIII is separated into two streams. The lighter fraction (b.p.-200°C) stream IX, is directed up the column C-2, passing the air and water cooling units AC-2, WC-2, a reflex tank RT-2, is divided into two streams. The first pump P -3 is fed into the column C-2 as a cold irrigation, the second one is fed by the pump P -7, and it is removed from the unit into the HCT -2 commodity tank.

The heavier fraction (200-360°C) stream X, being cooled from contact with the cooled fraction (b.p. - 360°C), is fed to the reflux of the column C-2, condenses on the surface of the regular packing and flows down to the bottom of the column.

Fraction (200-360°C) stream X from the bottom of the column C-2 is divided into two streams, the first is pumped by the pump P-4 through the heat exchanger HE-2 and returns to the bottom of the column C-2 to maintain the temperature in it. The second stream is pumped by the pump P-5 through the air and water cooling units AC-3 and WC-3 to the commercial reservoir HCT -3.

Columns C-1 and C-2 are equipped with the necessary instrumentation and automation to maintain a stable temperature and pressure of the process.

The given scheme on an industrial scale, depending on the properties of polymer raw materials and technological parameters of production, on average, allows to obtain 10-20% (mass.) of the fraction b.p.-200ºC 30-50% (mass.) of the fraction 200-360°C and 20-30%

(mass.) Of the fraction (> 360 °C). Among the by-products, 3,0-5,0 % (mass.) of light hydrocarbon gases (0,5-1,0 % mass.) and coke residue are formed.

The resulting fuel components will meet the requirements of [16-17] in terms of the content of harmful impurities, in particular sulfur. Other indicators shown in Table. 2, indicate the possibility of their compounding with commercial technological and boiler fuels, in order to improve their properties and simplify the technology of their application.

4. Conclusions

The presented technology makes it possible, by non-catalytic thermo-destructive processing of polymer raw materials, to obtain a fairly wide range of products that, according to the given quality indicators, can be used to improve both the properties of technological and boiler fuels.

The positive aspects of the proposed technology include: a lack of expensive sophisticated equipment designed for high operating pressure and temperature; a lack of a system for creating a vacuum and expensive consumables, in particular catalysts; the ability to integrate into existing technological schemes; the use of secondary polymeric materials as raw materials - solid household waste.

The industrial introduction of this technology at the enterprises of the main manufacturers and, most importantly, consumers of technological and boiler fuel, allows us to solve important scientific and practical problems, which include: improving the quality of fuel and ensuring the rapidly growing demand for fuel material in the absence of oil raw materials.

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