CARBONIZATION OF POLYESTER AND COTTON CLOTH FOR PRODUCTION OF THE GAS WITH HIGH HYDROGEN CONTENT

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Abstract

Simultaneous conversion of wastes, which have different compositions and properties, is important for domestic organic waste utilization. The material that contains both synthetic and natural polymers (waste of clothe consisting of 65 wt. % polyester and 35 wt. % cotton) was chosen to study the carbonization.
Stage mechanism of carbonization for mixture of polyester and cotton was determined based on research of carbonization of pure polyester and pure cotton with heating rate of 10-15 °C/min.
Analysis of the results of cloth carbonization without the use of catalyst showed that the obtained dry gas at the outlet of water cooler is enriched in CO (above 20 vol. %), non rich of hydrogen (below 14 vol. %) and methane (below 8 vol. %).
Nano-structured Fe-Catalyst of Institute of the Physical Chemistry of NAS of Ukraine and porous magnetically-separable Ni-Catalyst of Indian Institute of Petroleum for volatile conversion to increase hydrogen yield were used.
The influence of carbonization parameters and additives of catalysts on an increase in volatile conversion degree and composition of the obtained gas was studied. High-reactive coal and dry gas with hydrogen content more than 30 vol. % were obtained as the result of Indian and Ukrainian catalysts tests.

Keywords: *carbonization, wastes, polyester, cotton, hydrogen*

Introduction

It is not always possible to separate the various organic wastes before conversion into valuable products. The researches of the conversion of various organic materials (wood, paper, cotton, sunflower husk, lignin, lignite, and bituminous coal) have been conducted in Coal Energy Technology Institute of NAS of Ukraine since 2006 [1-3]. The results of the research of carbonization of the mixture of natural (cellulose in cotton) and synthetic (polyester) polymers are presented in this paper. Wastes of the cloth of polyester (65 wt.%) and cotton (35 wt.%) were selected for the study of carbonization to produce high-energy coal and gas with high content of hydrogen., Up to 25% of unreacted steam was evolved from the dry wastes during carbonization. New Ni- and Fe-Catalysts were used for the catalytic conversion of volatile matter of the cloth and an increase in hydrogen content in the obtained gas.

Test installations for organic waste carbonization

Two test installations for solid fuel carbonization of Coal Energy Technology Institute of NAS of Ukraine (CETI) were used for the research of organic waste carbonization.

The first modification of the installation for carbonization of CETI consists of ceramic reactor, two electric heaters, heat-insulation, voltage regulator, thermocouple, and filters. The ceramic reactor has a length of 120 mm, inner diameter of 15 mm, and wall thickness of 3 mm. A sample of the test material and thermocouple were in the middle of the ceramic reactor. Inlet and outlet of the ceramic reactor were closed with high-temperature filters. The installation for carbonation was used to research the influence of carbonization parameters on the yield of dry coal and the effect of carbonization temperature on the yield of moisture and volatile matter and change of state of samples during heating.

The second modification of the test installation (Fig. 1) is designed to determine the composition of dry gas produced during the carbonization of the samples.

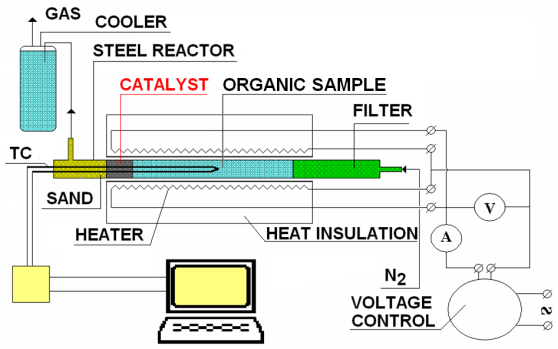

Fig. 1. Circuit of experimental installation with steel reactor for organic waste carbonization

Steel reactor with an inner diameter of 6 mm and wall thickness of 2 mm was put in the ceramic tube. The steel

reactor has an inlet for inert blow before carbonization and gas output to the cooler. Sample of initial organic material and thermocouple were placed in the middle of the steel reactor. Different catalysts for the conversion of volatiles were at the exit from the bed of the organic sample. A variant of mixing the catalyst with the initial organic material before carbonization was also used. The composition of the obtained gas was determined with chromatograph [2, 3].

The composition of organic wastes

The processes of carbonization of PET, cotton cloth, and cloth of polyester (65 wt.%) and cotton (35 wt.%). The composition of PET in terms of analytical weight, wt. %: C^a = 62.02, O^a = 33.04, H^a = 4.16, Ash^a = 0.08, and W^a = 0.7. The cotton cloth, wt. %: C^a = 41.98, O^a = 46.58, H^a = 5.87, Ash^a = 0.49, and W^a = 5.08. The cloth of polyester and cotton, wt. %: C^a = 55.40, O^a = 38.36, H^a = 4.84, Ash^a = 0.43, W^a = 0.97.

Experimental test procedure

The samples with weight of 3.7 g were loaded in the ceramic reactor. Carbonization was conducted with heating rate of samples of 12-15 °C/min during 30-35 minutes up to 470-500 °C (with the determination of influence of moisture and volatile output on the heating rate of the sample). The samples were held during 30 min at the temperature of 470-500 °C and cooled down to 100-120 °C. The obtained dry coal samples were unloaded and weighed.

Results of experimental research using ceramic reactor

The yield of dry coal from the dry sample of: PET was 19.3 %, cloth of polyester and cotton was 19.1 %, and cotton cloth was 22.8 %, respectively.

The influence of change of state and volatile output on the heating rate of the samples was determined by thermograms. The influence of volatile output on the heating rate of cotton cloth started at the temperature of carbonization of 171 °C. Heating rate of PET was changed at the temperatures: 65 °C (vitrification), 247 °C (melting) and 367 °C (volatile matter output). Heating rate of the cloth of polyester and cotton was changed at the temperatures: 66 °C (vitrification of polyester), 171 °C (volatile output from cotton), 295 °C (polyester melting), and 367 °C (volatile matter output from polyester).

As the results of proximate analysis, the composition of the obtained coal from the cloth of polyester and cotton was: W^a = 1.1 wt. %, A^a = 2.4 wt. %, V^a = 16.7 wt. %, C_{fix} = 79.8 wt. %, and LHV = 30.2 MJ / kg.

Results of experimental research using steel reactor and catalysts

For the experimental research in Coal Energy Technology Institute of NAS of Ukraine, porous magnetically-separable Ni-Catalyst for an increase in hydrogen content in the gas after waste carbonization was developed in Indian Institute of Petroleum, and nano-structured Fe-Catalyst for volatile conversion was developed in L.V. Pysarzhevsky Institute of Physical Chemistry of NAS of Ukraine. The catalysts were used for the conversion of cloth of polyester and cotton.

During carbonization of cloth of polyester and cotton (1 g) in the steel reactor without the use of catalysts, the content of hydrogen in the dry obtained gas was 5 to 8 vol. %, CO_2 was 45 to 70 vol. %. The composition of the obtained gas for the entire experiment was: H_2 = 7,7 vol. %, CO = 33.9 vol. %, CO_2 = 54.4 vol. %, and CH_4 = 4.0 vol. %. LHV of the obtained gas was 6.5 MJ/nm^3.

During carbonization of cloth of polyester and cotton (1 g), porous magnetically-separable Ni-Catalyst (1 g) was used after the fuel bed. During carbonization of the cloth, hydrogen content in dry gas varied 12 to 42 vol. % and CO_2 was 35 to 70 vol. %. The composition of the obtained gas for the entire experiment was: H_2 = 28 vol. %, CO = 23 vol. %, CO_2 = 46 vol. %, and CH_4 = 3 vol. %. LHV of the obtained gas was 7.0 MJ/nm^3.

Nano-structured Fe-Catalyst (1 g) was mixed with the cloth of polyester and cotton (1 g) before carbonization. During carbonization of the cloth, hydrogen content in dry gas varied 16 to 56 vol. % and CO_2 was 33 to 47 vol. %. The composition of the dry obtained gas for the entire experiment was: H_2 = 38 vol. %, CO = 18 vol. %, CO_2 = 40 vol. %, and % CH_4 = 4 vol. %. LHV of the obtained gas was 7.8 MJ/nm^3.

Conclusions

1. Stage mechanism of carbonization for mixture of polyester and cotton was determined based on research of carbonization of pure polyester and pure cotton with heating rate of 10-15 °C/min.
2. Coal with calorific value of 30.2 MJ/kg and gas with heating value of more than 7 MJ/nm^3 suitable for further conversion into a liquid fuel were obtained as a result of carbonization of the cloth of polyester and cotton using catalysts for volatile matter conversion.

References

[1] O.M. Dudnyk, I.S. Sokolovska Conversion of Ukrainian Low Grade Solid Fuels with CO_2 Capture. In: Proceedings of Twenty-Seventh Annual International Pittsburgh Coal Conference, 2010, Paper 22-2, pp. 1- 22.

[2] O. Dudnyk, P. Stryzhak, A. Trypolsky, I. Sokolovska. Conversion of solid organic waste using microchannel reactor. In: Modern science: research, ideas, results, and technologies. Collection of scientific articles, 2012, 3 (11), pp. 80-83.

[3] O. Dudnyk, P. Stryzhak, I. Sokolovska O. A. Trypolsky, E. Kalishin, V. Donets. Study of the process of sunflower husk carbonization. In: Modern science. Collection of scientific articles, 2011, 4 (6), pp. 74-78