The pyrolysis process of sewage sludge

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Abstract. The experimental investigations of pyrolysis process sewage sludge at different conditions are presented. As a result of executed investigations it was shown that syngas (mixrure of CO and H_2) used in gas engine can be obtained in pyrolysis process.

1. Introduction

Sewage sludge is the mixture of organic substances, sand, mineral impurities, water and more. There are toxic substances such as heavy metal, organic and inorganic acids and phenols as well as pathogenic flora in composition of sludge together with useful compounds (compounds of carbon, nitrogen and phosphorus). The problem of sludge utilization from waste treatment facilities has attracted attention to itself because of these-substance presence.

The main method of sludge disposal in Russia is storage on land of waste treatment facility. But this method has become less popular because of regulatory-system stiffening of nature conservation laws (lowering of permissible exposure limit in disposed sludge) and land deficiency for sludge disposal.

At the present time anaerobic digestion of sludge with generation of biogas is alternative method of sludge disposal. The calorific value of biogas is near 22 MJ/m^3. This gas is used for generation of heat. But 50% of organic substances in sludge stay unused behind anaerobic digestion, and in this case volume of fermented sludge is reduced just near 5% from original mass.

Therefore, sludge disposal problem is very important as before. It requires development of more perfect methods.

The methods should solve the problems: (i) lowering of sludge volume, (ii) generation of electrical and thermal energy from sludge.

In this paper low-temperature pyrolysis (process temperature—to 700°C) is proposed as method of sludge disposal. The syngas (mixture of CO and H_2) and carbon residue are result of two-stage pyrolysis [1]. The syngas is used for generation of electrical and thermal energy in gas engine. The carbon residue is by-product of this process.

The pyrolysis requires that sludge humidity was no more than 10%. Mechanical and chemical dehumidification reduces humidity to 50%. Thermal drying allows reaching humidity less 10%. But thermal drying requires the big energy demands. Therefore, it is effectually to use two-stage drying process: mechanical and chemical methods the first and then thermal methods.

In this paper the results of sludge pyrolysis experiment are presented. The composition of pyrolysis gases at different conditions and calorific value of sludge were defined.


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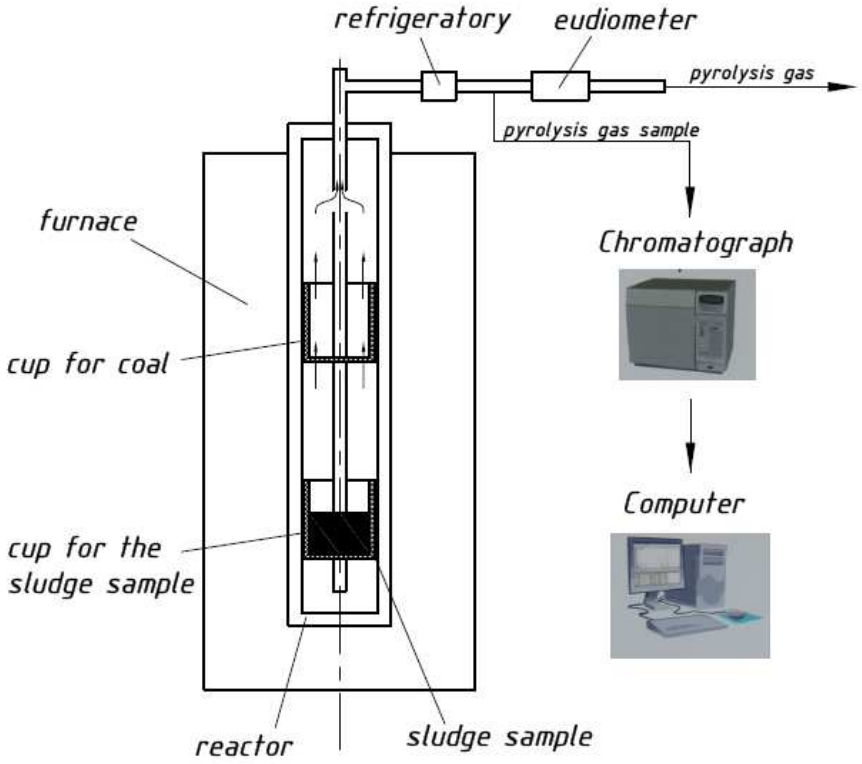


Figure 1. The experimental setup.

2. Experimental studies of sewage sludge

The sludge samples for experiments were taken from Kur'yanovskie and Podol'skie waste treatment facilities (Russia, the Moscow Region). The humidity of original materials were 97%. The ash content of dry part of original material was 40% and 30% respectively. The sludge samples were dried by thermal method. The final humidity of sludge after drying was 5%.

The experimental setup is shown on figure 1.

The first experiment was carried out without carbon filter; the second experiment was carried out with carbon filter. The volume and composition of the forming gases were measured by eudiometric and chromatographic methods respectively. In experiments, the heating rate of the raw material being processed was 10°C per minute, the mass of sludge sample was 15 gram. The mass of carbon in the second experiment was 15 gram. Before experiments the top chamber was heated up to temperature 650°C (the first experiment) and to 1000°C (the second experiment) that was held further at the constant level. After that the temperature of the bottom chamber was raised to 650°C.

3. Results and discussion

Changing of pyrolysis gas volume per kg of original material is shown in figure 2.

From the experimental data in figure 2, it is seen that pyrolysis gas volume with using of carbon bed is a lot more than pyrolysis gas volume without that.

The composition of noncondensing pyrolysis gases obtained during pyrolysis process without carbon filter is shown in table 1 (sample from Kur'yanovskie waste treatment facilities). It is

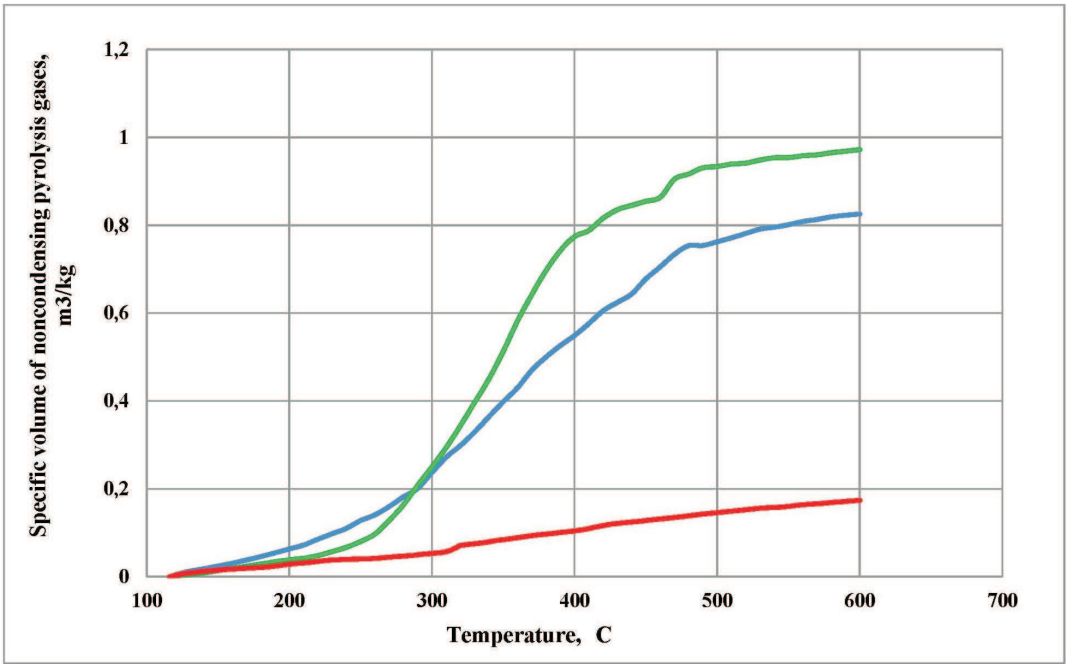


Figure 2. Dependence of pyrolysis gas volume per kg of original material from temperature (red line is pyrolysis process of sludge (without carbon filter), blue line—pyrolysis process of sludge with carbon filter (Kur'yanovskie waste treatment facilities), green line—pyrolysis process of sludge with carbon filter (Podol'skie waste treatment facilities)).

Table 1. The composition of noncondensing pyrolysis gases (without carbon filter).

t, °C	H_2, %	CO, %	CO_2, %	CH_4, %	N_2, %	C_nH_m, %	Other, %
260	0	2.8	46.3	0	40.1	0	10.8
350	1.1	5.4	69.8	0.9	18.7	0.5	3.6
470	7.2	5.8	56.6	7.1	5.2	7.3	10.8
520	14.1	5	33.9	15.2	7.3	7.9	16.6
570	3.2	3.2	13.5	7.9	43	7.5	21.7
620	30.5	2.9	20.3	19.1	6.7	11.3	9.2

necessary to notice that the highest concentration of burning gases (H_2, CO, CH_4, C_nH_m) was obtained at 620°C.

Dependence of noncondensing pyrolysis gas composition from temperature is shown in figure 3. The composition of noncondensing pyrolysis gases obtained during pyrolysis process with carbon filter is shown in table 2 (sample from Kur'yanovskie waste treatment facilities).

It is necessary to notice that the mixture consisted of essentially CO and H_2 (syngas) was obtained as result of pyrolysis with carbon filter. Changing of noncondensing pyrolysis gas composition is shown in figure 4.

From the experimental data it is seen that the maximal concentration of burning gases were obtained at temperature interval from 400 to 600°C (see table 2). At these temperatures the calorific value of obtained gases mixture is near 10 MJ/m^3. For example, the calorific value of

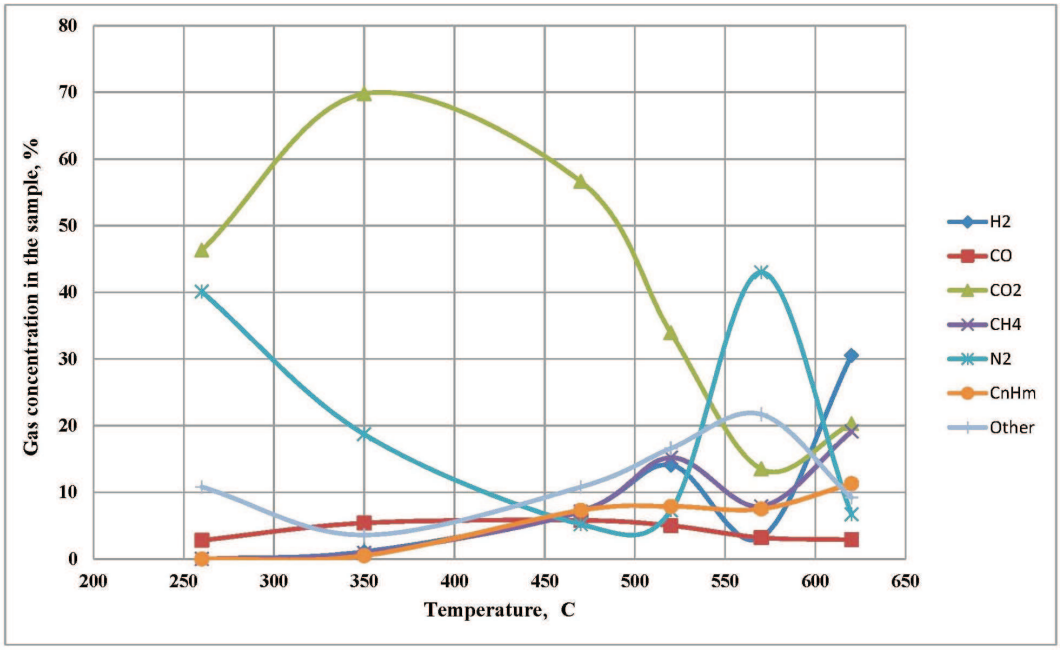


Figure 3. Changing of noncondensing pyrolysis gas composition (without carbon filter).

Table 2. The concentration of noncondensing pyrolysis gases at different temperatures (with carbon filter).

t, °C	H_2, %	CO, %	CO_2, %	CH_4, %	N_2, %	Other, %
340	10	21.6	0.4	0.7	60.1	7.2
400	54.4	31	2.2	1.2	8.7	2.5
540	54.5	29.3	2	2.2	9.4	2.6
600	60.5	24.5	0.3	1.6	7.5	5.6

natural gas is near 40 MJ/m^3, the calorific value of syngas from wood is near 11 MJ/m^3 [2].

The carbon residue was obtained in experiment except noncondensing pyrolysis gases.

The calorific value of sludge samples and carbon residue after the pyrolysis was defined by calorimeter (sample from Kur'yanovskie waste treatment facilities). It is 13.7 MJ/kg and 8.5 MJ/kg consequently.

4. Conclusions

The different compositions of noncondensing pyrolysis gas were obtained as results of experiment.

Use of carbon filter in pyrolysis process leads to formation of gas mixture consisted of essentially CO and H_2. This mixture uses in gas engine. Using gas-engine performances developed in JIHT RAS it can be take into account that 1 kg of dry sludge produce to 0.95 cube meters of syngas. It is from 4 to 5 times more than volume of noncondensing pyrolysis gas at pyrolysis (without carbon filter). And 1.4 kg of dry sludge is required for production of 1 kW of electric energy. As a comparison, 1 kg of dry wood is required for production of 1 kW of electric energy.

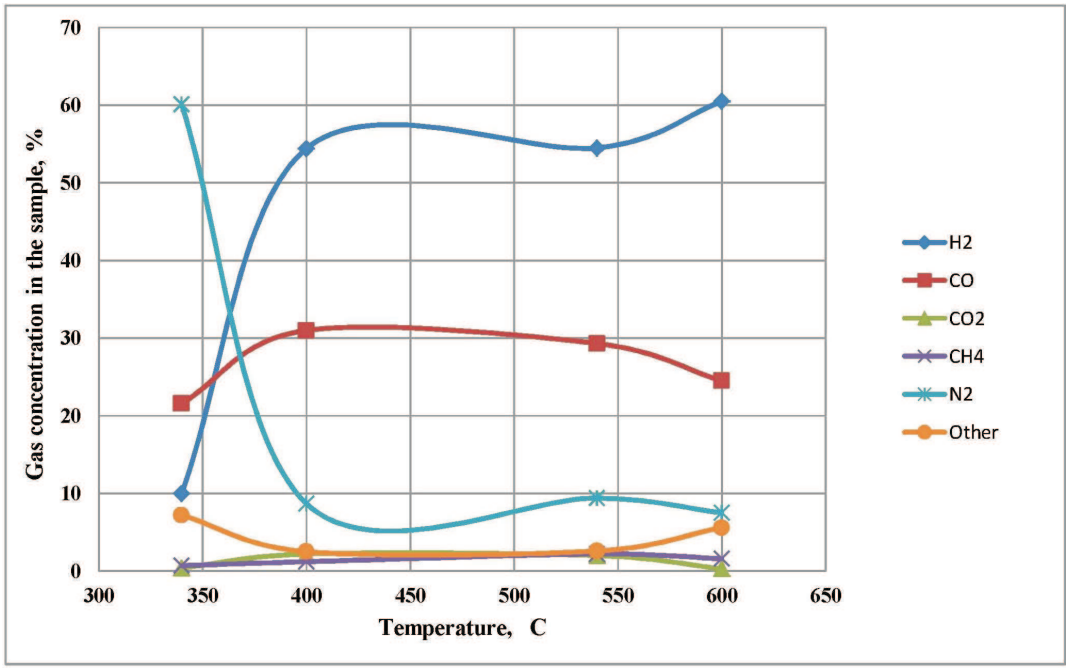


Figure 4. Changing of noncondensing pyrolysis gas composition (with carbon filter).

Acknowledgments

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References

[1] Zaichenko V M, Kosov V V, Kosov V F, Maikov I L and Sinelshchikov V A 2009 *Proc. 17th European Biomass Conference and Exhibition* pp 1085–1088
[2] Batenin V M, Zaichenko V M, Kosov V F and Sinel'shchikov V A 2012 *Chemical Technology* **446** 196–199