Biomass recycling heat technology and energy products

R B Tabakaev[1] P S Gergelizhiu[1] A V Kazakov[1] and A S Zavorin[1]
[1] Tomsk Polytechnic University, Tomsk, Russia

Email: TabakaevRB@tpu.ru

Abstract. Relevance is determined by necessity of utilizing of local low-grade fuels by energy equpment. Most widespread Tomsk oblast (Russian Federation region) low-grade fuels are described and listed. Capability of utilizing is analysed. Mass balances of heat-technology conversion materials and derived products are described. As a result, recycling capability of low-grade fuels in briquette fuel is appraised.

Introduction

The modern view on the problems in the power engineering industry development is directed to gradual increase in the percentage of renewable energy sources (RES) in the total power balance: governmental programs on involving RES in the fuel and energy balance have been adopted in more than 73 countries [1]. In turn, the Government of the Russian Federation has elaborated the Federal Law "On the Electrical Power Engineering" and "Strategy in Russia's Power Engineering Development by 2030", according to which it is required to put power generation systems based on RES with capacity more than 20 GW into operation by the end of 2030.

One of the RES types, in particular, organic biomass, has been studied within the framework of this research. The organic biomass proves difficult for the use as an energy source due to its high humidity and low combustion heat, which makes its direct combustion in the existing boiler equipment inefficient and inexpedient.

Biomass processed thermally into refined products, such as peat briquettes [2] and high-energy hydrogen-containing gas [3], is considered quite promising. However, prior to evaluating the possibility and expedience of such processing, data on material balance and properties of raw and final products should be obtained.

The main aim of this paper is to obtain information on the material balance at low-temperature pyrolysis of the Tomsk Region biomass, as well as on the properties of final refined products.

Biomass of Tomsk region (Russia)

The following major types of Tomsk Region biomass have been sampled (Fig. 1): the peat bogs of the Bakcharsky, Kolpashevsky, and Tomsky districts, wood wastes of the forest-industry complex, and sapropel of the Kolpashevsky district. Burning characteristics of the fuels under study are given in the Table 1.

The Sukhovsky and Arkadevsky peat bogs are filled with one and the same type of deposits - the lowland deposit referring to the group of decomposed peat, which was drained for industrial use. The Sukhovsky peat is compacted and can be characterised by high yield of volatile materials, high humidity and moderate ash content, so combustion proceeds at low

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

temperature values. The Arkadevsky peat is loose and can be characterised by high yield of volatile materials, moderate humidity and ash content, which also results in low heat of combustion.

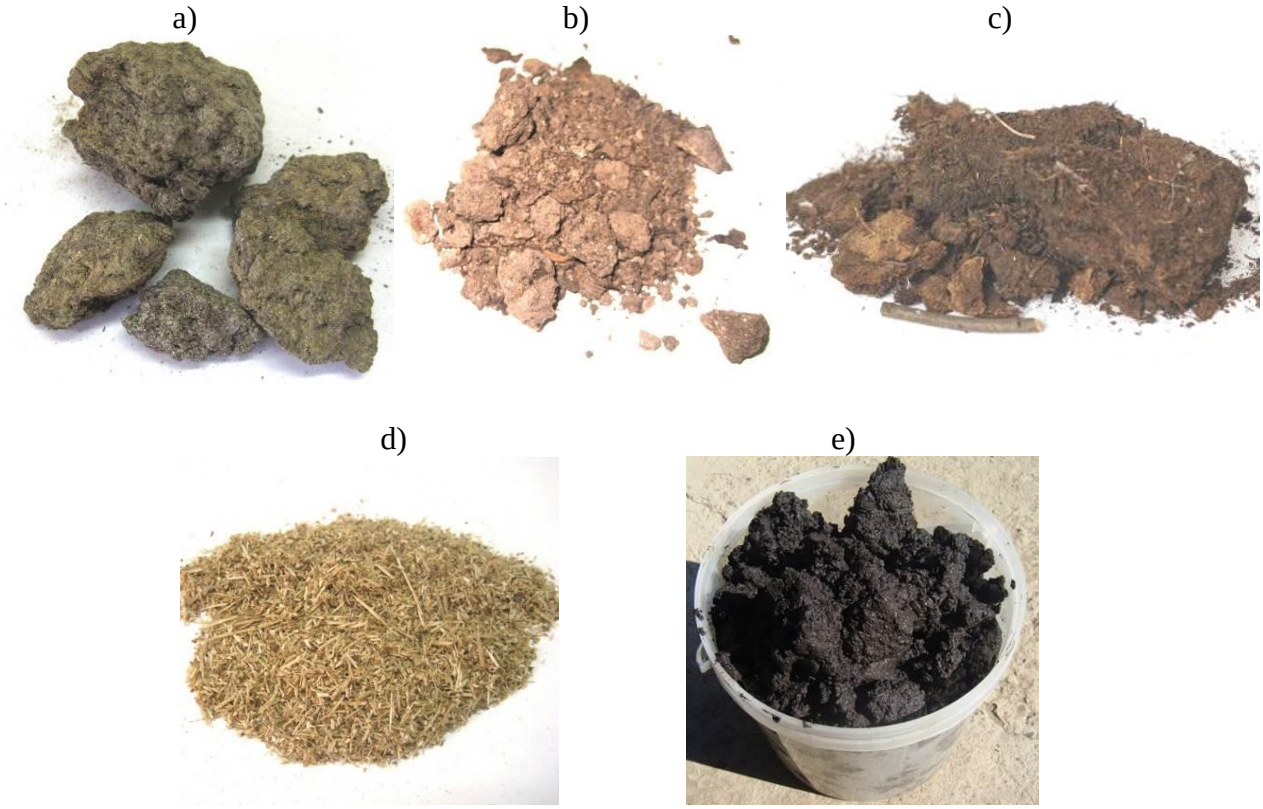

Figure 1. Researched types of Tomsk Region biomass
a) – Sukhovsky peat; b) – Arkadevsky peat; c) – Kandinsky peat; d) – wood chips;
e) – Karasevsky sapropel

Table 1. Burning characteristics of fuels under study

Burning characteristics	Peat			Karasevsky sapropel	Wood chips
	Sukhovsky	Arkadevsky	Kandinsky		
Ash content on dry weight basis A^d, %	39.5	31.5	9.1	38.4	0.6
Yield of volatile materials on dry ash-free basis V^{daf}, %	69.3	71.0	71.6	84.8	91.8
Heat of combustion on dry ash-free basis Q^{daf}, MJ/kg	12.8	15.2	19.8	12.5	19.1

The Kandinsky peat is brown and in its native state, can be characterised by high yield of volatile materials and high humidity. Contrasted to other types of peat, the Kandinsky peat has low ash content, and quite high (for a peat) combustion heat.

The sapropel samples were delivered from the Karasevoe bog situated near the Chazhemto village of the Kolpashevsky district. Sapropel is a viscous mass of high humidity; whose dry ash content is quite high, so combustion proceeds at low temperature values. Besides, its yield of volatile materials is about 95 %.

Wood chips of different timber species from the CJSC "Lesopererabatyvauschy kombinat "Partner-Tomsk" were used in the research as wood wastes of the forest-industry complex.

Heat-technology recycling of biomass

The samples of biomass listed above were subjected to low-temperature pyrolysis at a special laboratory facility for heat processing (Fig. 2). The processing temperature reached 450 °C with a maximum heater capacity (750 W) of the given facility, which enabled to obtain the highest yield of pyrolysis condensate. Material balance was comprised on the experiment completion (Table 2).

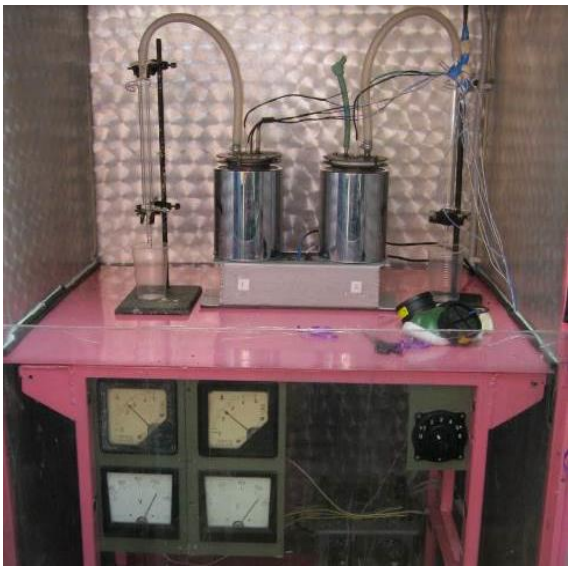

Figure 2. Photo of the laboratory facility for heat processing [3]

Table 2. Material balance in thermal technological processing of Tomsk Region biomass

Low-grade fuels	Yield of pyrolysis products on dry weight basis		
	Carbon residue	Pyrolysis condensate	Hydrogen-containing gas
Sukhovsky peat	60.7 ± 7.9	20.3 ± 1.6	19.0 ± 6.9
Arkadevsky peat	74.8 ± 1.9	12.0 ± 0.7	13.2 ± 1.5
Kandinsky peat	43.4 ± 0.5	26.2 ± 2.4	30.4 ± 2.9
Wood chips	31.1 ± 3.3	23.6 ± 4.4	45.3 ± 3.0
Karasevsky sapropel	67.4 ± 1.8	14.1 ± 3.1	18.5 ± 4.3

The composition of the gases emitted was registered over the range of temperature values from 200 to 450 °C with an interval of 50 C. The Khromatek-Kristall 5000.2 chromatograph was used for measurements. According to recommendations [4], combustion heat was calculated based on the defined composition. Table 3 comprises the averaged values of fuel gas composition and its combustion heat over the temperature value range 200-450 °C.

Table 3. Characteristics of hydrogen-containing gas

Low-grade fuels	Fuel gas composition, %					Averaged value of heat of combustion of fuel gas, MJ/m^3
	H_2	CO	CH_4	C_mH_n	CO_2+N_2	
Sukhovsky peat	25.9	9.4	10.8	11.8	42.2	16.3
Arkadevsky peat	27.6	9.1	9.7	10.6	43.0	15.2
Kandinsky peat	23.8	9.8	12.9	12.8	40.7	17.6
Wood chips	6.5	26.0	19.3	11.5	36.8	19.1
Karasevsky sapropel	26.8	7.6	10.2	12.8	42.5	16.6

Table 4 contains burning characteristics of carbon residue gained at low-temperature pyrolysis.

Table 4. Burning characteristics of carbon residue

Burning characteristics	Sukhovsky peat	Arkadevsky peat	Kandinsky peat	Karasevsky sapropel	Wood chips
Moisture of fuel as received W^r_t, %	0.0	0.0	0.0	0.0	0.0
Ash content on dry weight basis A^d, %	40.6	61.9	22.9	56.5	3.5
Yield of volatile materials on dry ash-free basis V^{daf}, %	25.1	18.6	23.3	19.8	15.7
Heat of combustion on dry ash-free basis Q^{daf}, MJ/kg	17.0	16.3	27.9	23.0	33.0

Analysis of Tables 2-4 enables to draw a conclusion that thermal processing of wood chips and the Kandinsky peat by means of low-temperature pyrolysis can be carried out both for the purpose of gaining high-energy fuel gas (high yield and high combustion heat) and producing peat briquettes from carbon residue (an extremely high combustion heat) [2].

The characteristics of the Sukhovsky peat pyrolysis products allow to consider them relating to power generation only after thoroughly studying the technical and economic feasibility of using it under specific circumstances.

High ash content of carbon residue leads to lowering the combustion heat and increasing the operating costs. For this reason, thermal technological processing of the Arkadevsky peat and Karasevsky sapropel into peat briquettes is not expedient. Low yield of gas makes them inefficient for fuel gas generation as well.

Summary

1. Wood wastes and the Kandinsky peat can be considered promising raw material for thermal technological processing both into fuel gas and peat briquettes.
2. The Sukhovsky peat may be used for power generation only after conducting a thorough investigation and feasibility study of its use in certain conditions.
3. Using the Karasevsky sapropel and Arkadevsky peat is considered unpromising due to low ash content of raw material and final products of thermal technological processing.

The reported study was partially supported by the Ministry of education and science of The Russian Federation (Government Order No. 2.1322.2014).

References

[1] Popel O S Reutov B F and Antropov A P 2010 *Thermal engineering* **11** pp. 909-918.
[2] Zavorin A S Kazakov A V Makeev A A and Podorov S V 2012 *Thermal engineering* **1** pp. 77-82.
[3] Zavorin A S Kazakov A V and Tabakaev R B 2012 *Bulletin of Tomsk Polytechnic University* **4** pp.18-22.
[4] *Teplovoj raschet kotlov (Normativny metod)*. Saint-Petersburg: Energiya, 1998. 256 p. [in Russian]