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Options for processing of aspen wood to carbon materials

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Options for processing of aspen wood to carbon materials

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Abstract. Thermochemical processing of aspen wood to produce carbon materials is of interest considering that it allows increasing the cost of its products several times and enhancing the sustainability of forest complex enterprises.Currently, the enterprises are confined to the manufacture of charcoal, although it is possible to produce other carbon materials, such as charcoal briquettes, activated carbon and oxidized coal.While processing aspen wood, it is feasible to arrange manufacturing charcoal briquettes. Increased mechanical strength and high bulk density of briquettes raises the range of economically viable transportation of manufactured products, i.e. logistics is being improved.To obtain stable quality activated carbon from aspen coal, water vapor activation is the least environmentally hazardous. For such activation implementation, we recommend using a rotary kiln equipped with a Z - shaped insert. For reasons of environmental safety, the oxidation of activated carbon is preferably carried out using hot, humid air. In this case, unlike liquid-phase oxidation, no wastewater is formed.

1. Introduction

Among hardwood aspen ranks second after birch by wood reserves in Russia [1].The most settled European-Ural part of the Khanty-Mansiysk Autonomous District, Bashkortostan and the Vologda region each has more than 100 million m^3 of aspen wood reserves, and another 8 entities each has such reserves of over 50 million m^3.

Asfast-growing species of woodaspen usually grows first in the felling.It turns out to be the main forest species near the wood enterprises of the European-Ural region.Despite the proximity to the processing enterprises, the industrial use of aspen wood is small.This can be explained by the widespread of core rot, the relatively low mechanical strength of wood and some other disadvantages [2].

In this regard arrangement of the pyrolysis process to procure charcoal has a good prospect, because the existing pyrolysis technologies allow manufacturing productsfrom wood of low quality and various sizesthat are in demand in the domestic and foreign market [3].

World trade in charcoal is developing rapidly. For 10 years (2007...2017), total imports of charcoal in the world increased by 1.63 times and exceeded 2.5 million tons [4].

Currently, there are eight main regions of charcoal consumption in the world, the total imports volume of which estimates 91% of the world volume. Near the territory of the Russian Federation there are three main centers, each of them consumes more than 450 thousand tons of charcoal per year. This is East Asia, West Asia and Western Europe.

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2. Materials and methods

Charcoal for research was received from the aspen wood growing in vicinities of Yekaterinburg. For activation we used a sample of industrial aspen charcoal (Russian standard 7657) obtained on a modular pyrolysis plant of the Modular Pyrolysis Retort Plant type at a final pyrolysis temperature of 600°C.Generally accepted methods of analysis were used to determine the quality indicators of charcoal and activated carbon [5]. The original aspen coal had typical quality indicators such as ash content, non-volatile carbon content and humidity (2.5, 84 and 1.2 %, respectively).

3.Results and discussion

The main factor determining both the output and the quality of the charcoal is the final process temperature (PT).The influence of PT on the content of non-volatile carbon (FC, %) in the charcoal during the pyrolysis of aspen in the PT range from 400 to 700 °C with an accuracy of 95% is described by the equation:

$$\mathrm{FC} = 53.35\ln\mathrm{PT} - 254.17 \tag{1}$$

Analysis of equation (1) indicates that the requirements of the Russian standard for the content of non-volatile carbon corresponds to the aspen coal obtained even at PT about 600 °C.Further increase of the final pyrolysis temperature is impractical, since it leads to a decrease of the charcoal output. Ash content of aspen charcoal meets the requirements of the current Russian standard for any PT up to 700 °C [1].

While processing of aspen wood on charcoal a large number of small fractions can be formed. Therefore it is feasible to arrange manufacturing charcoal briquettes which compare favorably with standard charcoal by significantly higher strength and density. The two interdependent indicators can be adjusted in the process of briquetting within sufficiently wide confines, therebythe range of economically viable transportation of manufactured productsraises, i.e. logistics is being improved.

Charcoal briquettes transportation costs about 2 times cheaper than a standard charcoal, which is clearly illustrated in Figure 1.

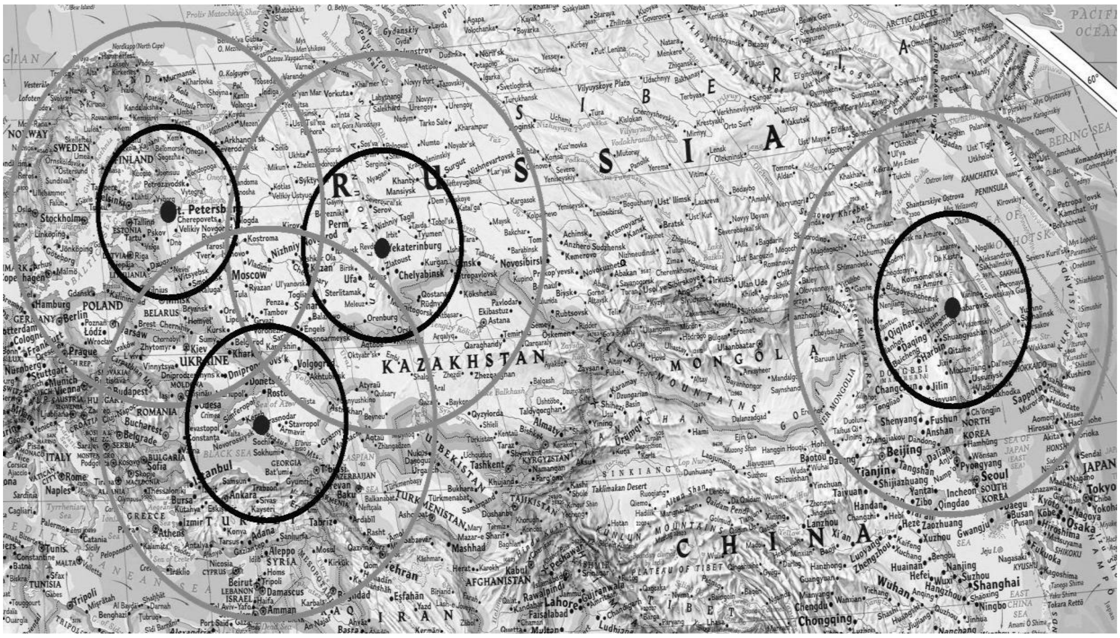

Figure 1. Areas of equal transportation costsof charcoal (smaller radius) andcharcoal briquettes (larger radius).

It can be seen in Figure 1, that sales region of charcoal briquettes covers an area 4 times larger, than the sale of standard charcoal with equal transport costs. Arrangement manufacturingcharcoal

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briquetteswill allow to organize the export of products even from regions of the Russian Federation relatively remote from the border. For example, it becomes possible to export from the Ural region to West Asia.Charcoal total imports to this region for the period of 2007 ... 2017 years. has grown more than three times and has good growth prospects.

Charcoal briquettesproduction technology using the Modular Pyrolysis Retort Plant type at the pyrolysis stage and not involving the application of an external binder is of interest. This technology can be used in cases where the supply of binder is difficult or economically inefficient.

The binding material in the charge was the droplet phase of the steam-gas mixture (SGM), which is formed at the stage of wood pyrolysis. After passing the SGM through the charcoal layer, in the charcoal there is more than 95% of the settled and soluble tar provided in the SGM [6].

According to this technology, first sawdust with moisture 30...55% and not more than 5 mm fraction is pressed without a binder application, so as after pyrolysis no grinding is required.Pressing is carried out using a hydraulic press at a pressing pressure of 200 kg / cm^2.Compressed sawdust in the form of briquettes is loaded into the pyrolysis furnace. Retorts with a charcoal obtained from the sawdust are loaded into the reactor without removing from the retort, and the next batch of waste is loaded into the pyrolysis furnace.During pyrolysis, SGM released from the pyrolysis chamber passes through the reactor. Provided this more than 95% of the settled and soluble tar, which are part of the SGM dropping phaseare deposited on the surface of the charcoal, and pyrolysis gases pass through the coal layer and then fed into the furnace, where they are burned.The mass obtained in the reactor, consisting of a mixture of coal and deposited tar, is directed to grinding and briquetting.

The pressing is carried out on a hydraulic press with a pressing pressure of 300 kg / cm^2. The resulting briquettes must be subjected to calcining at 600 ... 700 °C. Then, the calcined briquettes are cooled and packed.

Thus obtained briquettes meet the requirements of Technical conditions 2455-003-31235731-06.

Table 1. Indicators of the briquettes quality.

Indicator description	TC Requirements	Experiment briquettes
Non-volatile carbon content,%, not less	75	91.5
Ash content,%, not more	10	2.5
Humidity,%, not more	15	6
Density, kg / m^3, not less	571	580...780
The mechanical strength of the drop	The briquettes splitted	The briquettes didn't split

The most promising products of the charcoal processing are carbon nanoporous materials such as oxidized coal and activated coal.

To obtain activatedcarbon, we assume, water vapor activation is the least environmentally hazardous. For its implementation, we recommend using a rotary kiln equipped with a Z - shaped insert.The use of such a device makes it possible to obtain activated carbon of a standard quality [7].For reasons of environmental safety, the oxidation of activated carbon is preferably carried out using hot, humid air as an oxidizer.In this case, unlike liquid-phase oxidation, no wastewater is formed.

Thus, it is possible to obtain up to four types of carbon materials - charcoal, charcoal briquettes, activated carbons and oxidized carbon;

To obtain adequate dependencies of the activation process of aspen coal, a plan Complete Factorial Experiment 2^3 was chosen. The range of values factors was: activation process temperature (X_1) - 760 or 820°C, specific water vapor consumption (X_2) – 1.3 or 1.8 kg/kg of charcoal.The duration of activation based on previous experiments was within 90 ... 120 minutes. Response function - is output of activated carbon (Y_1, %) and its iodine adsorption activity (Y_2, %).

As a result, it was found out that theactivated carbon output from both aspen and birch is more influenced by the specific consumption of vapor. The activation process temperature has a lesser influence [8], and the influence of the duration of the process in the investigated range is insignificant, which is evident from the regression equation (2):

$$Y_1 = 54.03 - 5.68X_1 - 6.86X_2 \quad (2)$$

The stronger influence of the specific vapor consumption is also shown by the regression equation (3) regarding the activity of aspen activated carbon in iodine:

$$Y_2 = 76.6 + 3.9X_1 + 4.8X_2 \quad (3)$$

The microporous structure of aspen activated carbonis developed by about 15 ... 20% better than in birch activated carbon obtained under the same conditions, as indicated by the iodine activity indicator.Thus, it can be used in the same areas as standard birch activated carbon [9].Like other activated carbons obtained on the wood basis, the porous structure of aspen activated carbon has all types of pores - micropores, mesopores and macropores. This structure is promising for the manufacture of supercapacitors as a nanoporous carbon matrix.Currently, carbon materials of different origin which contain micropores smaller than 2 nm are used for supercapacitors, but it is promising to use materials containing meso - and macropores to increase the capacity [10].

The resulting aspen activated carbon can be further processed into oxidized charcoal using a simple installation [11], shown in Figure 2.

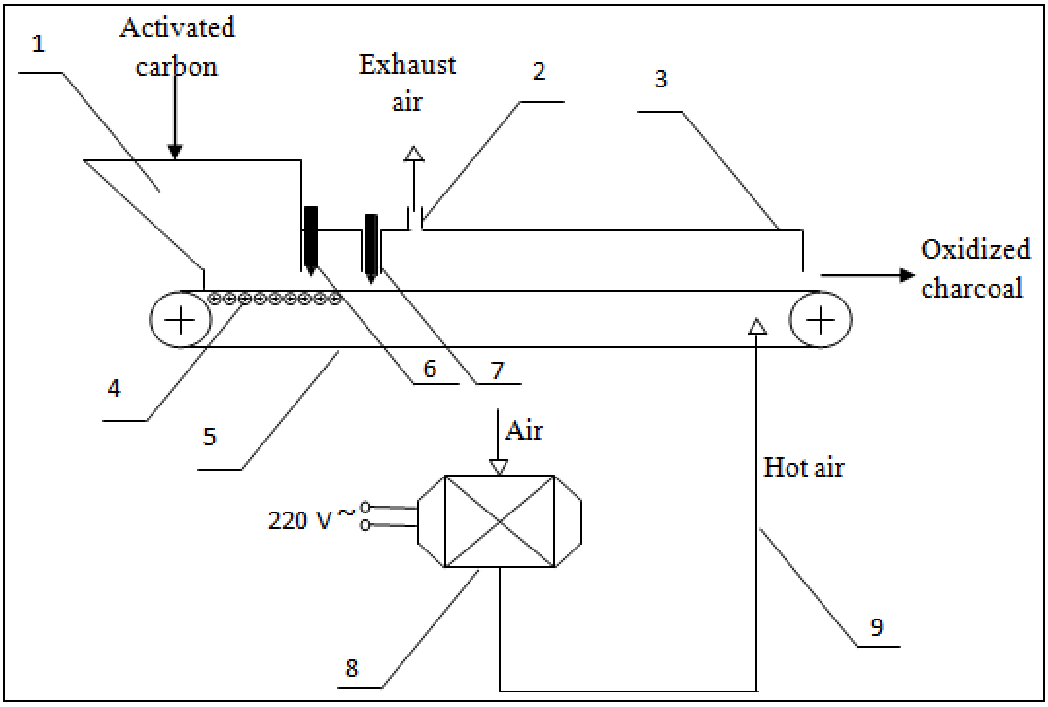

Figure 2. Structure of installation: 1 - loading funnel; 2 - air outlet; 3 - oxidation chamber; 4 - supporting rollers; 5 - grid; 6, 7 - gates for leveling the coal layer; 8 - air heater; 9 - hot air.

Oxidized charcoal can be used can be used in such sectors of the national economy as metallurgy, radio chemistry, food industry. Particularly, the high efficiency of activated carbon and oxidized charcoaljoint use for water purification in the food industry is shown.

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4. Conclusion

Aspen wood is an affordable and promising raw material for at least four types of carbon materials – charcoal, charcoal briquettes, activated carbon and oxidized charcoal.To obtain stable quality activated carbon from aspen coal, water vapor activation is the least environmentally hazardous. For such activation implementation, we recommend using a rotary kiln equipped with a Z - shaped insert. For reasons of environmental safety, the oxidation of activated carbon is preferably carried out using hot, humid air. In this case, unlike liquid-phase oxidation, no wastewater is formed.

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