Raw peat production and processing from flooded fields and approaches to maintain dehydration

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Abstract. The autonomous modular complex is energy efficient, capable to ensure year-round production of raw peat and its onboard processing thus transforming some part of fuel into thermal and electrical energy provided the complex is self-powered and generates energy for local consumers. The integrated scheme of modular units and energy intensity of raw peat production and processing depends on the preferred method of raw materials extraction. In general, the functional structure of a complex may include the following units: raw peat production, separation and crushing, formation of peat (raw peat) reserves, drying, generation of electrical energy for internal needs, production of commodity products (granules, gas, coke, fertilizers, electrical energy, etc.). To comply with the energy saving principle the autonomous production and processing complex with power self-generation focuses on such method of peat mechanical dehydration as gravity filtration and sedimentation. Magnetic treatment of a peat pulp may be used to intensify the moisture disengagement under the influence of gravity forces. The analysis of water separation intensity on a pulp did not reveal a clear influence of a constant magnetic field. However, the influence of an alternating magnetic field revealed explicit (more than twice) increase in the intensity of water separation in comparison with the basic test.

1. Introduction

Due to the increase in prices for hydrocarbon resources in the world market and lack of personal reserves in some European countries the raw peat materials are considered as one of the minerals able to cover a significant portion in the energy budget.

Russia with its largest peat reserves in the world is not able to hold the leading positions in production and utilization of such raw materials. The use of peat for power purposes may only bring benefit in long-range fuel regions having peat treatment enterprises and financial resources for the construction of peat stations. The use of raw peat as fuel for energy generation is quite competitive if used at a 100 km radial distance from the production site.

The main tasks of improving the peat production include the expansion of peat production, the improvement of its quality and the reduction of production costs. The solution of these tasks is bound to a large-scale introduction of advanced technology solutions, structures and complexes of process equipment, means and systems for processes control and management at all stages of production.

Until recently, the production schemes did not generally cover raw peat production without preliminary field drainage. The transition towards new economy places a priority on new machines and equipment thus ensuring the production without drainage of territories, for example, using

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excavation to extract peat raw materials. Autonomy, energy efficiency, year-round production of raw peat alongside with the production and processing of raw peat without big transportation legs shall become the main distinctive features of new machines and facilities [3, 4, 5].

2. Materials and methods (Functional structure of autonomous modular complex)

One of the options contributing to the implementation of the above approaches is the use of an autonomous modular complex under the RF patent No. 2599117 [9]. The complex ensures the production and processing of raw peat with its subsequent transformation into thermal and electric energy thus providing for energy self-efficiency and energy generation for local consumers, as well as for the production of energy-dense fuel. The process modules of the complex are united by an integrated transport system, as well as power, gas, heat, water and fuel supply networks connected to corresponding sources of power engineering modules, thus the technological facility is closed in a uniform information and measuring system of monitoring and control [9].

A number of design solutions is proposed depending on the production method and the end product manufactured via autonomous modular complex for raw peat production and processing from undrained peat field. The general works on the preparation of a modular complex for operation include assembly, installation of the equipment and field development, as well as energy generation units for individual needs and drying of raw materials.

The general facility-wide approaches to the production and processing of raw peat will be somewhat similar for all proposed schemes. The integrated scheme of modular units and energy intensity of raw peat production and processing depends on the preferred method of raw materials extraction [1].

The functional structure of a complex can be generally presented by the following units:

{1.} Raw peat production unit;
{2.} Raw wood separation and crushing unit;
{3.} Raw peat (raw wood) reserves formation unit;
{4.} Drying unit;
{5.} Energy unit for individual needs;
{6.} End product unit (granules, gas, coke, fertilizers, water distillate, electric energy, etc.).

Considering a complex as some system, it becomes obvious that the efficiency and stability of its equipment within a single process flow will depend on feedstock consistency. It should be noted that peat raw materials are not homogeneous in their composition and reservoir thickness: the near-surface section represents low peat decay degree with plant remains, and wood remains, which are different from the peat deposit itself in their strength properties, are unevenly placed along the deposit depth. Such irregularity requires the consideration of the above features to choose production equipment, in case of the need to separate the extracted volume, ensure its averaging, as well as full and zero waste utilization of excavated raw materials [3, 6, 9, 10, 11].

Before considering technological processes of raw peat production and processing using the autonomous complex let us define some conditions ensuring its smooth performance. The first condition is the need for deposit mining to full or target depth. The target depth is determined by at least the depth of a guaranteed movement through the generated water area of a floating facility and environmental standards. The second equally important condition is lack of large wood remains within the given water area. The third is the field mining along bands with at least step-size width of a complex and length corresponding to its free movement along the movement front, which ensure the deterministic movement of a complex. The fourth and mandatory condition is full power supply of a complex due to self-generation.

The milled method of peat production was selected and the energy intensity of raw peat extraction was determined to assess the efficiency of autonomous complex for raw peat production and processing.

The base-case scenario considered the annual production of 50 thousand tons of the 45% humidity milled peat through the development of an equivalent peat field 140 hectares in area, peat decay degree – 32%, stumpiness – 1.5, field life – 10 years. The basic technology implies the following field development operations: tree vegetation report along drain channel routes, removal of wood piles, main channel trenching and dredging, secondary drain trenching, stumping, field drain trenching, profiling and planning, etc. The core equipment includes the following machines and assemblies: MTP-13, MTP-71, MTP-71, MTP-52, DT-75 [9].

The total energy consumption made 50,190 kW·h, which covered field development regarding full range of mechanical operations over one year of machinery utilization.

The base-case scenario considers the following machines and equipment that ensure seasonal production of milled peat: MTF-14 cutter drum – 2 pieces, MTF-22 agitator – 2 pieces, MTF-43A harvester – 6 pieces, MTF-33B swath collector – 1 piece, MTF-72 stacker-truck – 1 piece, DT-75 tractor, harvesting machinery [7].

Energy consumption of machines and mechanisms consuming fuel over a year makes 51,673 kg or 1.03 kg/$t_{45\%}$, which is equivalent to 12.8 kW·h/$t_{45\%}$.

Cumulative energy consumption per 1t of 45% humidity raw peat makes 29.9 kW·h/$t_{45\%}$.

Let us consider the design solutions defining the structure of mining equipment within a complex successively and at high level.

3. Design solutions

First, let us consider the parameters of a conditional deposit and extraction of raw materials.

Peat raw materials excavated from a conditional deposit:

- Moss peat
- Peat decay degree R=30%,
- Peat humidity w_e=90%,
- Peat density γ_e=985 kg/m^3

These parameters make it possible to determine the product yield from 1m^3 of a peat deposit, which will make 0.164 t/m^3.

Thus, the total amount of produced raw peat is equal to 304,818.04 m^3.

The core mining equipment within the raw peat production unit {1.} may be the following [2]:

(1) Dipper shovel;
(2) Chain bucket excavator;
(3) Vertical cutter/auger;
(4) Hydraulic production;

It is obvious that the use of available equipment is not always possible directly from the production platform, therefore the transport and power module aggregated with an analog of the extracting machine and moving the machine along the entire platform shall be installed. For perception convenience at the first stage let us call such machines according to their equipment analogs.

It is advisable to use the MJK-310ST miller with rotary grinders equipped with cutting blades, power – 95-150 kW, process speed – 1 km/h for the development of undrained deposits.

(1) The EK-270LC dipper shovel with a 1.25 m^3 bucket, engine capacity N=132 kW, equipped with additional attachments representing a bucket clam to remove large wood remains was used to ensure the digging efficiency P=280 m^3/h. The required amount of such machines is one per complex [2].

(2) The second stage includes the use of the ETC-252M excavator, engine capacity N=154 kW, efficiency P =220 m^3/h, up to 3.5 m dig depth and 1 m face width. The operating speed is 150 m/h. The design should include a clamshell manipulator to remove large wood remains. The required amount of such machines is one per complex.

(3) The OJ-1.3K auger digger was used as an analog of a vertical peat cutter that grinds trees, roots and stubs located in a peat bed and efficiently operates in the conditions of soil freezing. The trench lines represent a trapezoid with 1.28 and 0.34 m base at 1.3 m height, traverse speed makes up to 1.5 km/h, capacity N=95-150 kW, efficiency P=1200 m^3/h [2, 4]. The machine capacity is sufficient to utilize one machine only. The advantage of this process is that all wood remains are destroyed in a deposit and additional separation is not needed. In the future, it is suggested to use three grinding mills

to create a homogeneous mass and an extruder to produce energy-dense fuel (pellets, granules). The production requires 4 pieces of such machinery and energy consumption will make 360,000 kW·h.

(4) The electrical cutter suction dredger Gidromekh 1600En with 37 kW capacity was used in hydraulic production. Solid mill with 0.5 s^{-1} rpm and the maximum torque making 10624 Nm. Soil output P=160-320 m^3/h, aggregate capacity N=315 kW [11].

Once produced the peat humidity ratio decreases thus changing its density and volume, and hence makes 233,644.9 m^3.

It is advisable to use a roll-type separator in the raw wood separation and crushing unit {2.} for production schemes (1), (2). The C1-6 disk separator with 1.1 kW capacity and 6 m^3/h efficiency will be used as an analog. At given capacity and efficiency the required amount of such machines is 7 pieces.

Crushing and separation lead to another change of peat parameters. The product yield will make 0.247 t/m^3 out of 1 m^3 of crushed peat. After crushing and separation, the total amount of raw peat will make 202,429.2 m^3.

Then, the schemes (1) and (2) use a grinding mill to create a homogeneous mass. According to preliminary calculations, the process will require three units of this equipment with energy consumption amounting to 185,559 kW·h.

Upon crushing and attrition, the raw peat materials have the following parameters:

• Peat decay degree R=30%,
• Peat humidity w_e=75%,
• Peat density γ_e=668 kg/m^3.

Thus, the total amount of peat raw materials after crushing and attrition makes 174,216.03 m^3.

The raw peat (raw wood) reserves formation unit {3.} depending on fuel type: fragmented peat, sod peat, pellets or granules, may be either totally missing, if fragmented peat is used as fuel, or have equipment similar to a peat spreader forming pieces of peat raw materials. An extruder and a screw press is required to make granules. The Huber ROS 3Q-800 with efficiency P=12 m^3/h and capacity N=3.0 kW was used for dehydration. The processing of the specified production volume will require 3 pieces of such equipment.

The drying unit {4.} includes two drum-type driers (normal 2222) with 9-14 t/h efficiency and 45 kW capacity. If 120,000 tons of peat raw materials shall be processed per year, the energy consumption will make 540,000 kW·h.

Summarizing the energy costs for four chains of the mining equipment and allocating them to the production target it is possible to obtain the energy unit costs for all considered options. Such costs will make respectively: for scheme (1) – 19 kW·h/$t_{45\%}$, scheme (2) – 20.5 kW·h/$t_{45\%}$, scheme (3) – 23.8 kW·h/$t_{45\%}$, scheme (4) – 18 kW·h/$t_{45\%}$.

To comply with the energy saving principle the autonomous production and processing complex with power self-generation focuses on such method of peat mechanical dehydration as gravity filtration and sedimentation. Magnetic treatment of a peat pulp may be used to intensify the moisture disengagement under the influence of gravity forces [7].

4. Structure of dehydration module

The autonomous process module of primary dehydration of hydropeat mixture represents an integrated system of mining equipment placed onboard a floating complex for production and processing of peat raw materials.

The equipment of the primary dehydration module combines three process stages into one, namely the reduction of moisture content of raw materials with 96.5 … 97% humidity to 95 … 95.5% through filtration in open filters without a vacuum. Dehydration to 88 … 81% humidity under hydromass filtration including through gravity filtration. The moisture content is reduced from 83 … 86% to 63% through continuous laminar pressing of a peat mass [1].

The module includes conveyors, elevators, and a pulp magnetic treatment device.

A series of comparative experiments on the dehydration of a peat mixture were conducted to assess the efficiency of magnetic treatment.

The study concerned the raw peat of the Northwest Peat Company (Tosno), which initial value of moisture weight ratio made 90%. Identical samples, including base samples, were taken from the material. Except for base samples, all samples were exposed to constant and alternating magnetic field with 30 mt induction rate. The intensity of magnetization was measured by multiple equal observations method via the IMAG-400C magnetic field strength meter taking into account its directivity. All samples were subjected to magnetization within 15, 30, 45 and 60 seconds to assess the impact of exposure time. Directly after magnetization all samples except base ones were placed in paper filters thus measuring time and volume of filtered fluid. The double (repeated) magnetization test was conducted under the influence of the alternating magnetic field.

The analysis of water separation intensity on a pulp did not reveal a clear influence of a constant magnetic field. The difference in experimental results fell within the limits of measurement accuracy.

The influence of the alternating magnetic field revealed explicit increase in the intensity of water separation in comparison with the basic test. Under double magnetization the intensity of water separation decreases but still remains above the basic option.

5. Conclusions

The study shows that in all cases the energy costs for process chains of the mining equipment are lower the corresponding costs for the basic option and thus make 29.9 $kW{\cdot}h/t_{45\%}$. Indeed, all proposed design solutions require further clarification; however, it is obvious that the first (1) and the fourth (4) solutions are the most promising.

It should also be stated that magnetization of hydropeat mixture may lead to increased intensity of primary water separation. The study of this matter is quite perspective and needs further experimental observations.

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