Economic Assessment of Low Humidity Peat Production Practice

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Abstract. The article presents a milled peat production practice based on deep bed drying up to a harvesting moisture content of 35%. The task of the developed technology is to minimize and stabilize the harvesting humidity in the field drying of peat, thereby reducing the time and thermal impact on the peat organic matter during a forced finish drying. The applied method of peat extraction provides for variable milling depth and differentiation of cycle harvesting to increase the number of cycles and the harvester seasonal output. An economic feasibility study has been carried out by the method of determining the operating costs per ton of a marketable product for each technological operation. It consists in a comparative assessment of two technological processes: the production practice based on intensification of milled peat drying up to a harvesting moisture content of 35% and the conventional harvesting of milled peat with moisture content of 45%. The developed technology of milled peat extraction makes it possible to ensure the required quality parameters in terms of humidity (≤ 35%) and to preserve natural bituminous components. Based on the economic assessment results, it has been found that there is a slight increase in operating costs per ton of a marketable product in comparison with the conventional practice.

1 Introduction

At present, in the mining industries of economically developed countries, the emphasis is on the production practices that can ensure the qualitative characteristics of raw material as early as at the geotechnological stage to reduce significantly the costs of its further processing and manufacture competitive products.

The main quality characteristics regulated by current peat production normative documents are humidity and ash content in the extracted peat. If the ash content is largely determined by natural characteristics of a peat deposit, the harvesting humidity depends entirely on the adopted peat extraction practice. The technological development of fragmented peat extraction for the purpose of fuel production and raw materials for advanced chemical processing is toward intensifying the natural drying process that is focused on reducing the harvesting humidity. As a rule, the moisture content of milled fuel peat that is supplied to a consumer is 45-50 %. Even if we take the average initial humidity of milled peat as 47 % or 0.89 kg / kg in terms of wetness, then 0.70 kg of moisture per kilogram of dried peat under factory conditions has to be removed, which is associated with significant heat energy consumption [1, 2]. In addition, this process is accompanied by an

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increase in temperature and time of exposure to peat, which leads to a change in the chemical group composition of peat and the loss of some valuable organic components [3].

The task of the developed technology is to minimize and stabilize a harvesting humidity in the field drying of peat, thereby reducing the time and temperature effect on its organic matter during a forced drying.

The production practice is represented by the following technological operations: peat deposit milling; fragmented peat tedding; peat harvesting by pneumatic machines; stacking.

The main variable parameter in the methods used for extraction of milled peat is a milling depth. Cycle peat deposit milling is performed by a dynamic cutting drum after precipitation to the depth of 25-30 mm provided that a layer of 45-50 mm thick is formed (Figure 1). In the second and subsequent cycles after precipitation, a cutting drum makes a layer of the fragmented peat that has remained in a production field and of the peat additionally milled at the depth of no more than 10-12 mm [1].

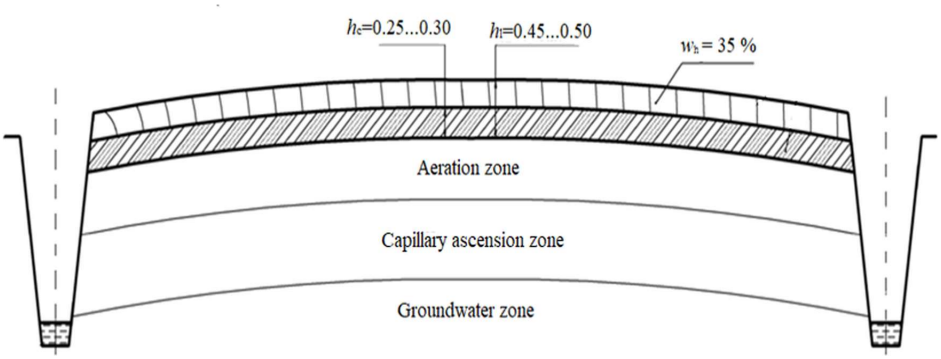

Fig.1. Peat bed pattern.

The method of fragmented peat drying in a deep bed is conducted in two layers. The maximum evaporation of moisture occurs in the upper layer, and the lower one is critical, it largely prevents the negative impact of the deposit on a peat drying (Figure 2). The critical layer is made 30 mm thick in the upland peat deposit, and it is 25 mm thick in the lowland peat deposit [4].

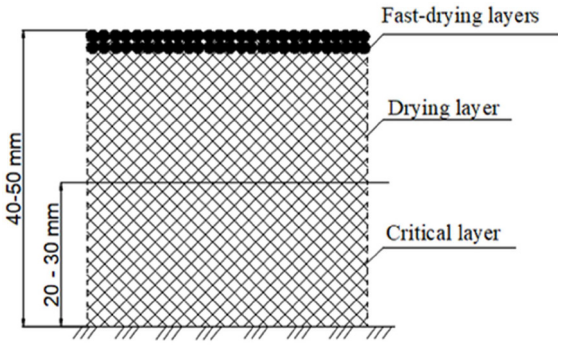

Fig.2. Deep bed drying.

The next operation in a technological cycle is tedding. To intensify drying within a single-day cycle duration, one tedding is performed if the category of drying is high and two-time tedding in case of medium and weak drying categories. Tedding in the top of a fragmented peat layer is performed at the depth of 20-25 mm.

It is advisable to harvest the top layer of milled peat by pneumatic machines. The pneumatic method of harvesting has significant advantages over the mechanical one.

Firstly, the lightest dry particles, that is, with the lowest humidity are sucked first. Secondly, it excludes the complementary peat deposit milling, which does not increase a harvesting humidity [5-7].

After harvesting, the peat deposit is milled to a depth of 10-12 mm together with the remains of the previous peat in order to create a layer of 45 - 50 mm thick for the next cycle.

The purpose of the economic feasibility study is to make a comparative assessment of two technological processes: the production practice based on intensification of milled peat drying up to a harvesting moisture content of 35% (the developed method) and the pneumatic harvesting of milled peat with moisture content of 45% (current or conventional method).

The costs of the peat deposit drainage, preparation and servicing of production sites do not depend on the technological process of peat extraction, therefore, they have not been taken into account in the economic feasibility study. With the same qualitative characteristics of a peat deposit and the equal production schedule, the differences in economic assessment of the technological processes are determined by values of the milled peat cyclic and seasonal harvests, quantity of marketable products and productivity of technological machines. Therefore, to conduct the economic assessment of the proposed practice of extracting milled peat with no more than 35% humidity, the methodology of determining operating costs per ton of marketable products is taken for each technological operation of the process.

Cost estimate includes the following input data:

- location area – Pskov region;
- type of peat deposit – upland;
- peat decay degree – 30%;
- stumpiness of peat deposit ≥ 1%;
- storage loss – 7% for peat with 45% moisture content and 10% – for peat with 35% moisture content;
- number of a single-day technological cycles – 36;
- milling depth of harvesting the peat with 45% moisture content – 8.25 mm; average milling depth of creating a thick layer of peat with 35% moisture content – 11 mm;
- technological machines: milling machine – BF-6.5; tedding machine – FCS-9.6; harvester – MPTU-30; stacker – AMKODOR-30; tractors: for milling and harvesting – MTZ-1221, for tedding – MTZ-82;
- design cycle harvesting: for 45% moisture content peat – 12.36 t / ha, for peat with intensification of drying to moisture content of 35% – 11.95 t / ha;
- re-tedding in a cycle: for peat drying in deep layers – 1.5, and for 45% moisture content peat – 1.

2 Method used

The operational performance of machines for milling, tedding and harvesting is determined by formula:

$$S = 0{,}1\,\upsilon_{\text{т}} \cdot K_{\upsilon} \cdot b_{\text{d}} \cdot K_{\text{w}} \cdot K_{\text{c}} \cdot K_{\text{m.t.}} \quad (1)$$

where $\upsilon_{\text{т}}$ is theoretical design (passport) speed of tractor or self-propelled vehicle, km / h; K_{υ} is velocity factor; b_{d} is design operating tool width; K_{w} is utilization factor of design operating tool width; K_{c} is cycle time factor; $K_{\text{m.t.}}$ is factor of available machine time.

The operational performance of the stacking machine is determined by formula:

$$V = V_{\text{p}} \cdot \gamma_{\text{b}} \cdot K_{\text{m.t.}} \quad (2)$$

where V_p is technical performance, m^3 / h; γ_b is bulk density of milled peat of harvest moisture, t / m^3.

The speeds for milling a peat deposit are determined by the engine power. The speeds for harvesting milled peat with pneumatic machines are calculated on the assumption of entire dried peat harvesting and are checked by the power of a tractor engine.

To calculate the cost of a machine shift in technological operations, a preliminary assessment of operating costs is carried out [8].

The specific fuel consumption for each operation is determined by formula:

$$m_f = m_{en} \cdot P_{en} \cdot K_{m.t.} \cdot K_f \cdot K_{en.l} \cdot t_{sh} \quad (3)$$

where m_{en} is specific fuel consumption by the internal combustion engine, kg/(kW·h); P_{en} is engine power, kW; $K_{m.t.}$ is factor of available machine time; K_f is coefficient that takes into account the idle operation of engine and flittings; $K_{en.l}$ is coefficient taking into account the total engine load; t_{sh} is shift duration, h.

The cost of diesel fuel (C_f) is determined by formula:

$$C_f = m_f \cdot C \cdot K_l \quad (4)$$

where C is cost of a kilogram of diesel fuel, RUB; K_l is coefficient that takes into account the consumption of lubricants.

The cost of basic wages and salaries with payroll charges and incentive payments (C_W) are determined by formula:

$$C_w = T_h \cdot K_{in} \cdot K_s \cdot t_{sh} \quad (5)$$

where T_h is hourly rate of wage, RUB; K_{in} is coefficient taking into account incentive (bonus) payment; K_s is coefficient that takes into account social fund and pension contributions.

The depreciation cost (C_D) of a tractor and technological machines are calculated as follows:

$$C_D = \frac{C_{ch} \cdot P_m \cdot K_{tr}}{100(P_{sh.o} + P_{sh.a})} \quad (6)$$

where C_D is depreciation charges; P_m is machine price including VAT, RUB; K_{tr} is coefficient taking into account transport costs and installation work; $P_{sh.o}$ is number of shifts per year in peat extraction operations; $P_{sh.a}$ is additional number of tractor shifts.

The number of shifts per year in peat extraction operations ($P_{sh.o}$) can be calculated using the following formula:

$$P_{sh.o} = P_{c.s} \cdot \tau_c \cdot m_{cr} \cdot m \quad (7)$$

where $P_{c.s}$ is standard number of cycles; τ_c is planned cycle duration, days; m_{cr} is planned repetitiveness of operation in a cycle; m is planned repetitiveness of operation due to precipitation.

The maintenance costs are determined using the depreciation cost formula, but the deductions are taken as 15% for a tractor and 12 % for machines.

Costs per ton of marketable peat for milling, tedding and harvesting operations (C_i) are determined by formula:

$$C_i = \frac{C_{m.h} \cdot n \cdot m}{S \cdot q_u \left(1 - \frac{\delta_{st}}{100}\right)} \quad (8)$$

where $C_{m.h}$ is cost of a machine-hour, RUB; n is repetitiveness of operation in a cycle; m is repetitiveness of operation due to precipitation; S is operational productivity, ha / h; δ_{st} is loss of finished products during storage, %.

The stacking costs per ton of commercial peat (C_{st}) are determined as follows:

$$C_{st} = \frac{C_{m.h} \cdot K_{st}}{V \cdot \gamma_b \left(1 - \frac{\delta_{st}}{100}\right)}, \quad (9)$$

where K_{st} is stacking factor; γ_b is bulk density of milled peat of harvest moisture, t / m^3.

3 Results and Discussions

Working capacity of machines are calculated by formula (1) and presented in Table 1.

Table 1. Calculations of machine working capacity

Production operations	Production practice with deep bed drying (w_h = 35 %)							Conventional production practice (w_h = 45 %)						
	υ_T, km / h	K_υ	B_d, m	K_w	K_c	$K_{m.t.}$	S ha / h	υ_T, km / h	K_υ	B_d, m	K_w	K_c	$K_{m.t.}$	S ha / h
Milling	10.9	0.92	6.5	0.94	0.79	0.83	4.84	12.6	0.92	6.5	0.94	0.82	0.83	5.77
Tedding	11.4	0.97	9.6	0.95	0.70	0.85	6.82	11.4	0.97	9.6	0.95	0.85	0.85	7.34
Harvesting	5.87	0.95	3.65	1.0	0.77	0.85	1.33	4.75	0.95	3.65	1.0	0.87	0.85	1.22

Table 1 shows that in conventional production practice (w_h = 45 %), the working capacity of machines in milling operations is 13.5 % higher due to a higher speed and a shallower milling depth as well as a higher cycle time factor compared to the production practice with deep bed drying (w_h = 35 %). The working capacity in tedding operations is 7 % higher in the in conventional production practice, which is stipulated by the fact that its cycle time factor is higher by 17.6. The working capacity of a pneumatic harvester is 9 % higher in milled peat production practice with deep bed drying due to the weight reduction of peat with 35 % harvest humidity.

The applied method of peat extraction provides for a variable milling depth and differentiation of cycle harvesting, which allows increasing the number of cycles by 25 % and the seasonal output of the harvester by 18 %. At the same time, under favorable weather conditions, there are no areas unharvested. The increase in cycle harvesting is significantly influenced by more intensive moisture removal from the dried layer with the aid of better aeration, which ultimately leads to enhancement of moisture removal from peat particles in the form of steam.

The study of the bitumen content in cotton grass-sphagnum peat with a decay rate of 25-30 % extracted by the proposed technology shows (Table 2) its increase by 1.7...2 times within the required temperature range in comparison with the conventional peat production practice.

A decrease in the harvesting moisture content of milled peat during a natural drying on the aerated bedding in the extraction technology with a critical layer of 25-30 mm ensures the maximum retention of high-mobility bituminous components in the raw material owing

to reducing the time and thermal impact on peat organic matter during subsequent forced finish drying.

Table 2. Bitumen content in organic matter of peat when it is dried in a shaft-mill dryer (AC-1)

No	Magnitude of temperature effect on dried peat, K	Peat humidity at drier inlet, %		
		35	45	50
		Bitumen content, %		
1	313	3.51	3.51	3.51
2	473	4.15	2.43	2.08
3	523	4.88	2.87	2.35
4	553	5.86	3.45	2.98
5	573	2.89	1.71	1.52
6	673	1.74	1.02	0.89

To calculate the cost of a machine shift in technological operations, an estimate of operating costs is preliminary carried out according to formulas (2 - 9). All the calculations are summarized in Table 3.

Table 3. Summary results of calculating costs per ton of commercial peat of conditional humidity

Production operations	Production practice with deep bed drying (w_h = 35 %)			Conventional production practice (w_h = 45 %)		
	Production per hour, (ha, m^3)	Cost per operator hour, RUB.	Costs per ton of commercial peat, RUB.	Production per hour, (ha, m3)	Cost per operator hour, RUB.	Costs per ton of commercial peat, RUB.
Milling	4.84	2353.89	49.7	5.77	2353.89	39.0
Tedding	6.82	1432.4	32.2	7.34	1432.4	18.7
Harvesting	1.33	3756.8	262.6	1.22	3756.8	267.8
Stacking	154.73	3432.75	20.0	179.03	3432.75	17.0
Total			364.5			342.5

Analyzing the results of cost calculations for individual operations per ton of marketable peat in terms of conditional humidity of 40 %, one can conclude that milled peat harvesting is the most costly production operation (70...80 % of total costs). As compared to conventional production scheme, the cost of peat harvesting in the developed production practice based on the intensified deep bed drying is 2% lower. However, there is an increase

in costs by 21.5 % in milling operations and by 42.0 % in tedding operations due to an increase in milling depth, a loss of machine capacity and a reduction of cycle time factor.

4 Conclusions

Thus, the production practice with deep bed drying makes it possible to extract milled peat with the best indexes of humidity and stabile chemical composition, as well as with the maximum retention of bitumen components in organic matter. Based on the economic assessment results, it has been found that there is a slight increase by 6.2 % in operating costs per ton of a marketable product in comparison with the conventional practice.

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