Excavating and loading equipment for peat mining

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Excavating and loading equipment for peat mining

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Abstract. Recently, the issues of sustainable development of Russian regions, related to ensuring energy security, are more urgent than ever. To achieve sustainable development, an integrated approach to the use of local natural resources is needed. Practically in all north regions of the Russian Federation, peat as a local natural resource is widespread, which has a practical application in the area of housing services. The paper presents the evaluation of technologies for open-pit peat mining, as well as analysis of technological equipment for peat production. Special attention is paid to a question of peat materials excavating and loading. The problem of equipment selection in a peat surface mine is complex. Many features, restrictions and criteria need to be considered. Use of low and ultra-low ground pressure excavators and low ground pressure front-end loaders with full-range tires to provide the necessary floatation in the peat bog environment is offered.

1. Introduction

A particularly attractive region for production of an advanced peat as a renewable source is north and north-west of the European part of Russia. The development of peat fuels utilization would increase energy security and reduce costs in the local heating.

The draft of the Energy Strategy until 2035 had been created in 2015 during difficult time for Russia [1]. The strategy outlines strategic goals regarding development of renewables as reducing the consumption of traditional fossil fuel (coal and gas), minimizing the environmental strain from fuels and energy field activities, and securing the reliable and sustainable biofuels supply to remote regions along with reducing costs on imported fuels.

The strategy examines only few of biofuels as an alternative to traditional fuel; particularly it indicates peat and firewood. The blueprint of the next Strategy pays much more attention to the energy generated from renewables. Among that, the local fuels (peat, municipal solid and wastes from the wood production and agriculture) are highlighted as a promising sphere, especially their utilization in the remote areas of Russia [1].

Open pit mining is the process of mining a peat deposit by means of a deep pit excavated using one horizontal bench. One of the challenging problems for surface mining operation optimization is choosing the optimal excavator and loader fleet. This problem involves choosing a fleet of excavators and loaders and designing a long-term mining schedule that minimizes transportation and other fixed costs [2].

The type of excavator and loader selected for use in a surface mine depends on the type of deposit to be extracted and specifications of the environment, such as the bench height.
Equipment selection for any mining operation is of prime importance because the type of equipment selected determines the mode of operation and consequently the output or rate of production [3].

This paper presents an investigation of the excavator and loader selection on the structure of open-pit peat mining.

2. Materials and methods

Peat is a highly organic substance composed of decaying bog plant matter. Peat is very soft, easily penetrated organic soil and unstable material. According to Unified Soil Classification System (USCS) peat is a highly-organic soil. The highly-organic soils usually are very compressible. They are classified into one group, designated by the symbol Pt. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils [4].

Removal of peat is the most commonly used procedure for peat excavation. This procedure is frequently used under the following conditions:
- peat deposit is large in size;
- peat deposit is deeper than 1 m;
- water is present at all times;
- free water level is high;

The problem of equipment selection in a peat surface mine is complex. Many features, restrictions and criteria need to be considered (Figure1). The equipment selection process begins with the initial conception of peat development [5].

![Figure 1. Effective parameters in selection fleet types [5]](image)

Natural structure and properties of the peat change to the least when dredging by the excavator. The excavation difficulty class of peat soil is low [6].

The way does not demand high extent of drainage of a peat deposit. The excavator method of peat mining is conducted in the vertical direction, practically to the full depth. Fire danger decreases and dust content of atmospheric air at extraction of peat comes down to zero. Besides, the coefficient of peat extraction from the deposit for a milling way of peat extraction increases up to 0,9 in comparison with existing 0,5. The technology reduces terms of input of the areas in operation as it excludes labor-consuming and long terms of preliminary and operational drainage, carrying out a wide complex of fields’ preparatory work.
Technology of open-pit peat mining:
- Stripping of the top layer: frontal loader → transport → storage.
- Excavation of peat: excavator → transport → storage.

There are operational factors, which are not allowing completely realizing high potential traction and power properties of wheel mover and engines, which should be considered by justification of rational operating modes and an objective choice of peat equipment.

The peat industry by the nature of productions has no analogs in other industries. The principal factor for hauling and loading machines is their capacity. Specifics of peat equipment units and conditions of their operation define the following factors:
- nature of excavating and loading operations;
- high deformability and low bearing ability of a peat deposit (Table 1);
- low indicators of traction and grip of drive tires properties and the increased slipping of tractors on a peat deposit surface;
- basic characteristics and design features of the equipment.

| Peat type     | Degree of decomposition (von Post) | Moisture content w, % | Density, kg/m³ | Shear strength τ, kPa |
|---------------|------------------------------------|-----------------------|----------------|----------------------|
| Oligotrophic  | H4                                 | 79                    | 750            | 68                   |
|               | H5                                 | 81                    | 820            | 54                   |
|               | H6                                 | 85                    | 880            | 40                   |
| Eutrophic     | H4                                 | 77                    | 780            | 98                   |
|               | H5                                 | 79                    | 860            | 80                   |
|               | H6                                 | 83                    | 860            | 48                   |

The choice of the permissible specific wheel pressure on the bearing surface is determined not only by the shear strength of a peat deposit surface [1]. With the increase in the specific pressure of the wheels on the bearing surface, the energy expenditure on overcoming the resistance to destruction of the upper peat deposit layer increases.

3. The evaluation study

The most common problems related to the peat mining are: settlement of peat deposit, low bearing capacity of peat, poor stability of peat deposit during excavation and a high ground water table. Deep excavation on a peat deposit with a high ground water table can lead to instability of soil. Various solutions were proposed to resolve these problems. After determining the bucket capacity, the excavator is examined for the pressure it applies to the ground. The ground bearing capacity is a determining factor here in selecting or eliminating some excavators [8]. One of the most important considerations in peat excavation is the soil trafficability. This is of major importance in equipment selection for peat mining.

Shear strength and cone index depend on various factors, including peat texture, a decomposition degree, density and, most importantly, moisture content [9]. A cone index (CI), shear strength (τ) and a deformation modulus (E value) are the parameters used in the soil strength classification (Table 2) developed under the Eco Wood Operations Protocol for eco-efficient wood harvesting on sensitive sites [10]. Peat as a soft soil strength determines the bearing capacity and traction capacity of soil, and thereby soil trafficability.

The soil bearing capacity is usually considered as the maximum allowable wheel contact pressure. The actual wheel pressure, however, is difficult to assess, because the true contact area depends on the tyre and soil properties [11-13]. In the EcoWood soil strength classification, the estimation of allowed
bearing capacities (contact pressure of vehicles) is based on nominal ground pressure equations. Cyclic action machines are most often used for excavating and loading on open pits. The low Nominal Ground pressure (NGP) is a key parameter (Figure 2) of excavating and loading equipment (Table 3).

Table 2. Eco Wood soil strength classification

| Classes | Soil strength description | Cone index CI, kPa | Module E, MPa | Shear strength τ, kPa | Allowed soil bearing capacity NGP, kPa |
|---------|---------------------------|--------------------|---------------|----------------------|--------------------------------------|
| 1       | Strong soil               | >500               | >60           | >60                  | >80                                  |
| 2       | Average soil              | 300-500            | 20-60         | 20-60                | 60-80                                |
| 3       | Soft soil                 | <300               | <20           | <20                  | 40-60                                |

Peat as a soft soil can be excavated with no difficulty using a hydraulic backhoe. The material will flow very easily and must be supported and contained to be excavated to any significant depth. Peat is very sensitive to vibration and other disturbances which cause the material to flow. The type of an excavator and a loader selected for use in a surface mine depends on the type of peat to be extracted and specifications of the environment, such as the digging depth.

Figure 2. Excavating and loading equipment for peat mining

The low ground pressure hydraulic excavator complete with a set of low ground pressure tracks to provide the necessary floatation in the bog environment.

Table 3. Effective parameters in selection equipment

| Equipment                | Bucket capacity, m³ | Track width, mm | Tyres | Nominal ground pressure NGP, kPa |
|--------------------------|---------------------|-----------------|-------|---------------------------------|
| Hydraulic excavator      | 1.5-2.0             | 1200-1500       | -     | 28-16                           |
| Front End Loader         | 4.0-6.0             | -               | 66-43.0 R25 SB-1 | 28 |

The low ground pressure excavators are capable of peat mining on drying fields, but wetter peats will require wider tracks. Low and ultra-low ground pressure excavators used to be hard to obtain away from peat extraction sites. Many more peat contractors now have wide tracked excavators as part of their fleet. Machines which work at the bog have to be with low ground pressure and excavators will require a moderate bucket reach to reduce movements. On the soft peat
soil, excavators have the excess power which is completely used by the increase of a bucket volume. Custom-engineered wide track pads and a longer body reduce overall machine pressure. Curved-end track pads minimize damage to foliage leaving less trace of operation. These machines weigh less, have a smaller footprint and are designed to travel without damage to the undercarriage.

Figure 2 shows photos of the wide tracked low ground pressure excavator and the low ground pressure front-end loader. The front-end loader AMKODOR 342P is designed for peat mining and equipped with full-range tires with the extra-low pressure to provide the necessary floatation in the bog environment. These tires allow them to work on the soils with low bearing capacity. In the peat mine, shovels and loaders are used for the purpose of loading the peat into dump trucks. The hydraulic shovel is used with a bucket capacity of 2 m$^3$ and the front end loader — of 6 m$^3$ bucket capacity (without teeth). The hauling operation is performed by overburden and peat dump of capacity 10 m$^3$.

4. Conclusion
Peat is characterized with high organic content, high water content, high compressibility and low bearing capacity. This paper has presented some of peat mining conditions. Mining techniques have been discussed under two major aspects of peat mining: peat excavation and peat removal. Results from the excavating and loading fleet evaluation indicate that there is a scope for reduction in the size of excavating fleet, thus, allowing the peat mining companies to reduce initial investments. The wide tracked low ground pressure excavator and the low ground pressure front-end loader will be a good decision for open pit peat mining. The described choice of the equipment considers physic mechanical properties of peat deposit, ensuring the maximum productivity of the equipment, and also an opportunity to operate the same equipment. At the final stage of fleet evaluation, it is necessary to define the required number of tractor transport units for one excavator, taking into account conditions of transportation and distance.

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