A potential application of in-pit crushing-conveying and dewatering system in peat mining

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Abstract. The purpose of this paper is to analyse the application of fully mobile plants for raw peat crushing, mixing and separating of wood inclusions and for mechanical dewatering in peat open-pit mines to increase the efficiency of mining. In-Pit Crushing and Conveying Systems (IPCC) which characterized by their economic efficiency, reduction of labour costs, haulage costs, fuel consumption and pollution (dust and noise) compared to conventional shovel-truck systems are well known. Full mobile In-Pit Crushing-Conveying and Dewatering System includes an excavator, two mobile plants: crushing and dewatering plants. The considered technology of primary processing of excavated raw peat has the following advantages: reducing trucks fleet; reducing transportation costs; an opportunity of continuous processing of peat; reducing the energy consumption of the crushers; eliminating the need to build water treatment plants in factories due to returning squeezed water back to the pit.

1. Introduction

In-pit Crushing and Conveying Systems (IPCC) are characterized by their economic efficiency, reduction of labour costs, haulage costs, fuel consumption and pollution (dust and noise) compared with conventional shovel-truck systems are well known [1]. Open-pit mining is the process of mining a peat deposit by means of a deep pit excavation using one horizontal bench [2]. One of the challenging problems of the open-pit mining operation 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 [3].

The conventional shovel-truck system is widely used in mining peat deposits [4]. The system comprises discrete loading and haulage units whose outputs are characterized by their cycle times. Deep excavation is the most cost-efficient means for size reduction of peat deposit. The type of an excavator and loader selected for use in a surface mine depends on the type of a deposit to be extracted and specifications of the environment, such as the bench height.

Tractor and semitrailer transportation within and outside of the open-pit is the most common method of raw peat transportation to the stationary plants for processing. Haulage costs are always a significant part of the capital and operating costs in large peat mines. Diesel fuel costs for a tractor are significant and can range from 15 to 35% of the facility utility costs. The number of trucks increases with increasing haulage distances. Semitrailers are well suited for short hauls (less than two kilometers). Crushers, mixers, separators and dewatering equipment are situated at the peat processing plant. As a result, fuel, tyre, and depreciation costs per ton of raw peat increase [5].

In-Pit Crushing-Conveying (IPCC) Systems have been known in the mining industry for many decades. The cost-efficiency and high reliability of IPCC and truck systems, compared to conventional shovel-truck systems alone, make them more attractive for use in modern mining operations [6]. This paper presents an analysis of the potential use of full mobile crushing, conveying and dewatering plants in the structure of open-pit peat mining.
2. An application of In-Pit Crushing-Conveying and Dewatering Systems in a mining peat deposit

2.1. Open-pit peat mining

Peat is a very soft, easily penetrated organic soil and unstable material. According to the Unified Soil Classification System (USCS) peat is a highly-organic soil. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils [7]. Removal of peat is the most commonly used procedure for peat excavation. An excavator method of peat mining is conducted in the vertical direction, practically on all its depth. Today open-pit peat mining is carried out in the following way: excavation → loading → transporting → storage.

A raw peat material can be excavated with no difficulty using a hydraulic backhoe. The material flows very easily and must be supported and contained to be excavated to any significant depth [8]. Mostly, equipment of cyclic action for excavating and loading is used on open pits. In the conventional system, the excavated peat raw material is usually transported by semitrailers to the stockpiles.

The most common problems relating to peat mining are settlement of peat deposit, low bearing capacity of peat, poor stability of peat deposit during excavation and a high groundwater table. One of the most important considerations in peat excavation is the soil traffic ability. Peat as a soft soil strength determines the bearing capacity and traction capacity of the soil, and thereby soil traffic ability. Transporting raw peat and waste (wood and water) after excavation in the most economical and efficient way is the most important operation of peat open-pit mine.

There is a good reason to consider the appliance of IPCC systems on in-pit peat mining. Full mobile In-Pit Crushing-Conveying and Dewatering System in open-pit mining includes an excavator, two mobile plants: crushing and dewatering plants. The excavator is located on the peat deposit loads raw peat directly into the hopper of a mobile crushing plant, instead of feeding a semitrailer. The principal factors for hauling machines are the high deformability and low bearing ability of a peat deposit. In view of this, the excavator and mobile plants have a tracked chassis for better moving. The plurality of loading positions is based on the relative position of the peat excavator and the crusher mobile plant and a plurality of excavation positions, such that at each of the plurality of loading positions, the bucket traverses an arc passing above the hopper [9, 10].

In the crushing plant, a raw peat material is separated, mixed and crushed. After crushing plant the separated peat material is transferred into the hopper of a mobile dewatering plant by belt conveyor. After the material is conveyed to the stockpile. These way semitrailers would not be fed near the excavator, so it could avoid sinking. A short summary of the functional capabilities of In-pit equipment is shown in Table 1 [11].

Application of the full mobile In-Pit Crushing-Conveying and Dewatering System in open-pit mining allows improving the quality of excavated raw peat material, which allows reducing hauling costs.

![Diagram of In-Pit Crushing-Conveying and Dewatering System](image-url)

**Figure 1.** The process design of mining and processing on mobile plants
Table 1. Functional capabilities of In-pit equipment

| Equipment                        | Functionality                        | Optimum transport distance, m | Waste            | Reduced waste, % | Raw peat bulk density, kg/m³ (after the operation) |
|----------------------------------|--------------------------------------|------------------------------|-----------------|-----------------|---------------------------------------------------|
| Hydraulic excavator              | Excavation, loading                  | <20                          | Big wood pieces | 30              | 850                                               |
| Mobile crushing-separating plant | Crushing, mixing, separating, conveying | <20                          | Small wood pieces | 80              | 820                                               |
| Mobile mechanical dewatering plant| Mechanical dewatering, mixing, conveying | <20                          | Water           | 45              | 660                                               |
| Front End Loader (wheeled)       | Loading, transporting                | <30                          | -               | -               | 650                                               |
| Tractor semitrailer (wheeled)    | Transporting                         | > 500                        | -               | -               | 700                                               |

2.2. Mobile crushing plant

The most of peat deposits are traditionally developed with operations of stumps grubbing. At peat production take a significant amount of the wood remains which put in stacks near the peat field. The system of wood remains utilization practically isn’t exist. At best wood sorts, saws and burns in boiler rooms, but in general volumes of their utilization are significantly lower than extraction volumes from a deposit. The concentration of a large amount of the dry wood remains is an additional factor of fire danger on the peat field and surrounding territories. Thus, one of the main problems of the peat industry is the development of complex ecologically balanced technologies of production and processing of all organic resources which are in the peat deposits [12].

Raw peat crushing is the first controlled size reduction stage in the process of peat mining. This is the main process in the preparation process for further size reduction. A distinctive feature of a mobile crusher is that the crushing, mixing of peat and the separation of wood inclusions is carried out in one technological device simultaneously [13].

The process of separating is based on two core aspects: detecting and deleting of big wood pieces during raw peat excavation, and removing of small wood pieces at the stage of raw peat processing. The challenge is to remove the wood at the stage of excavation and stage of comminution to ensure it does not consume energy unnecessarily at the following stage of peat processing.

The composition of low decomposed peat and high decomposed is an important stage of processing. In this case, the peat fiber structure will serve as a physical conditioner during the subsequent dewatering stage.

A single roll milling crusher can be used as the working unit to preliminary crushing of low abrasive and soft aggregates. The plant is equipped with cutting knives, so wet, sticky peat material is more easily handled. Cutting knives have shape so that energy consumption is reduced. Also, the milling roll acts as a flywheel, contributing to smooth operation and efficient use of power. Single roll milling crushers are simple in design and construction, long-lasting, economical, and versatile.

This way raw peat is loaded into the hopper of the plant. Big wood pieces are captured and thrown away and raw peat is reduced by the cutting elements. Then the processed peat is conveyed into the next plant for further processing.
The system task of a single roll milling crusher is a reducing excavated raw peat to conveyable size (crushing ratio below 1: 10). After the enrichment operation is a value product (reduced peat) and a non-value product (small wood pieces).

2.3. Mobile dewatering plant

The analysis shows that in the open-pit peat mining it is expedient to include the operation of mechanical dewatering of raw peat. A single screw press of continuous action can be used as the working unit. It is a well-known tool, which is used for dewatering organogenic materials. An application of a single screw press of continuous action as preliminary mechanical dewatering can reduce the moisture content of excavated raw peat by approximately 10%.

The mobile dewatering plant consists of the hopper, single screw press, belt conveyor and a bunker of detached water. The detached water is returned to an artificial reservoir, which is accumulated after open-pit peat mining through a flexible pipe. The intensity of the subsequent drying of granulated peat products grows in the field, in plant conditions. Hauling costs of transportation of raw peat are reduced after the dewatering process.

For example, in a production of the peat granulated fuel with a program of 35 thousand tons a year, the volume of peat raw materials is about 240 thousand m³. In usual conditions, this volume of peat raw materials at a water content of 88% is transported to the processing plant for crushing, mixing, separating and preliminary mechanical dehydration, further mechanical processing, and drying of finished products.

The preliminary mechanical dewatering of this amount of raw peat directly in field conditions from 88% to 80% can return back to a peat deposit 84 thousand tons of water. Besides, preliminary mechanical dewatering of raw peat in pit allows reducing by 40% the hauling costs on transportation of less wet raw peat to the processing plant.

2.4. Advantages of applying full mobile In-pit Crushing-Conveying and Dewatering System

The process design of full mobile In-Pit Crushing-Conveying and Dewatering System in the mining peat deposit is shown in Figure 1. The process is continuous but cyclical. Excavator horizontal bench is limited by length. When one cycle is over, plants are moved by a front-end loader.

In full mobile In-Pit Crushing-Conveying and Dewatering System, the preliminary raw peat treatment is placed in a pit and then the enriched material is conveyed to the subsequent process phase.

In the crushing plant, excavated peat material is crushed, mixed and separated. Raw peat material is rendered cleaner (without wood chips) and has a more compact texture. In the dewatering plant, the water content of raw peat material is reduced from 88% to 80% approximately.

Wastes of treatment (wood pieces) are laid out to the stockpiles, and then are conveyed away from the pit, the detached water is returned into an artificial reservoir. It allows reducing hauling costs of transportation to the peat processing plant. Moreover, it saves an environment of the peat deposit.

After this treatment, a raw peat material has less density, which allows reducing hauling costs of transportation excavated raw peat material [14]. Mining method selection is one of the most critical and problematic activities of mining engineering. The selection of an appropriate mining method is a complex task that requires consideration of many technical, economic and environmental factors. The appropriate mining method is the method, which technically feasible for the peat deposit conditions, while also being a low-cost operation [15].

The most relevant method for open-pit peat mining is In-pit Crushing and Conveying Systems. It is evident from the case study presented that the planning of open-pit operations using IPCC systems cannot simply be based upon shovel-truck designs [16].

3. Conclusion

IPCC systems are attractive by low operating costs, but the unique sequencing restrictions must be meticulously planned and designed. Peat mining operation provides the integration of two additional
plants: crushing and dewatering. The crushing plant includes the hopper, single milling roll, and conveyer belt. The dewatering plant includes the hopper, single screw press, conveyer belt and bunker of detached water. These plants are continuous-motion, unattended plants and have simple construction designs. After processing on the plants excavated raw peat material becomes cleaner (without wood), mixed, crushed and contains less water. The main reason for the implementation of mobile crushing plants is the optimization of material transport around and out of the pit on its way to the waste dump or processing plant. Separating wood wastes and peat mechanical dewatering in the pit have several benefits: saving in operational, fleet maintenance, labour costs for hauling plenty of water and reduced environmental impacts.

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