Primary dehydration of peat on floating mining platforms

E A Vagapova, I N Khudyakova and D V Fadeev
Saint-Petersburg Mining University, 2, 21st Line V. O., St. Petersburg, 199106, Russia
E-mail: rez.love@mail.ru

Abstract. The use of peat as a local type of fuel is advisable for many remote areas of our country. Improving the efficiency of peat resources makes it possible to ensure energy security of the country and reduce emissions to the atmosphere, as compared to the use of hydrocarbon energy sources. Autonomous floating platforms utilized for peat extraction and further treatment call for a scientifically sound selection of their parameters, which is specified by the equipment and dehydration technology applicable for the extracted raw peat materials. A study of filtration properties and chemical composition of impurities in aqueous solutions or peat pulps enables a rational approach to water separation and improvement through a short-term magnetic exposure. The identified outputs form the cornerstone of innovative technologies for primary peat dehydration.

1. Introduction
Peat is an organic rock formed by fallen or partially decomposed plant material in peatlands, favoured by warm moist climatic conditions with little oxygen and no more than 50 % of mineral content per dry matter. Peat is an environmentally friendly, widely distributed resource. When it is burned, 50 times less sulfur dioxide is emitted into the atmosphere in comparison with fuel oil or coal. There is almost no carcinogenic benzo pyrene. Russia has the largest peat reserves in the world. Unlike natural gas, though, this type of fuel is on average more expensive in terms of energy production. However, peat as a fuel is more profitable than coal or diesel fuel for a transportation leg up to a hundred kilometers from the place of extraction. Therefore, the use of peat is economically feasible.

Peat extraction and processing are complex physical, chemical and mining processes that require special knowledge of physical and chemical mechanics of dispersed materials, taking into account the changes to occur in the structure of wet materials when exposed to drying [1]. Water content in natural peat deposits makes up 86–95 %. It is necessary to use modernized reliable and easily repairable equipment that prevents the escape of raw peat materials, separated from a peat bed, from the working body of a mining excavator [1–5]. Alternatively, it is required to continuously produce a peat slurry, deliver it to a floating platform by hydro transport and subsequently centrifuge or extract excess moisture, which is the most costly way compared to conventional excavation [6–9].

2. The hydraulic method of peat extraction
Peat is a complex structure that contains chemically bound water; osmotic water held inside peat aggregates and responsible for the swelling of hydrophilic colloids that have structural lattices forming partitions permeable to water; mechanically bound water that comprises capillary, immobilized, intracellular water entrained on cell structures and the water in closed pores (as a result of plant remains interlaced); as well as free water [6]. Free and partially mechanically entrained moisture can be removed
by mechanical pressing. To remove the remaining moisture, it is required to apply thermomechanical, thermochemical or other methods that initiate water separation from hydrophobic structures of raw peat. The optimized drying process involves additional energy costs to ensure the proper operation of technological equipment [10]. At the same time, reducing moisture content in raw peat can take quite long. As a consequence, any intensification of the process with a minimum of energy costs can make this raw material more attractive.

Hydraulic peat extraction is considered to be the most effective method for the development of wetland deposits. Meanwhile, there is no need in dewatering the territory and whatever a peat depth it is possible to conduct the production of peat. Moreover, a climate-neutral economic activity is also feasible. However, hydraulic extraction is mainly geared towards the dehydration of raw peat materials. Raw peat contains about 90% humidity, peat slurry – 96–97 %, whereas commercial peat – 40 %. Moreover, natural drying of peat requires a significant investment of time, money and special areas relevant for the implementation of this process, thus making the process climate and weather dependent [10].

To make raw peat highly competitive over imported coal, oil and gas, it is necessary to have innovative mining equipment enabling the development of numerous irrigated peat deposits [1].

As evidenced, hydraulic extraction mostly relies on a screw and knife milling machine. It is used to mix milled peat with water, forming peat slurry, in which peat acquires a moisture balance and turns into a free-flowing form, thereby losing its inherent rheological properties. The suction line is equipped with a submersible soil pump lined up with a centrifugal deck pump, while a floating platform is moved by a pressure pile drive.

The existing peat dehydration technology involves pumping peat slurry to the fields where the latter, once drained, loses up to 60–70 % of moisture in natural conditions for several weeks. For example, to produce 300 tons/day, an area of 3.5 hectares is required to provide adequate peat drying. This dramatically reduces the attractiveness of this extraction method. Alternatively, it is proposed to use floating systems and carry out primary dehydration directly on board.

One of the effective methods for the extraction of raw peat is hydro-production through hydropeat technology. Of particular importance is primary dewatering of peat slurry, for which it is usually poured onto the surface of a drained site.

It is known that peat dehydration commonly includes three stages.

1. Reducing moisture content in a raw material to 95–95.5 % by vacuum-free settling or filtering in open filters. Filtering is fast. The optimization of the process is possible when coagulating peat slurry with colloidal iron oxide.

2. Removing water under a pressure of 0.05–0.2 MPa or in a vacuum of 0.045–0.07 MPa. Dehydration is carried out until a moisture content of 88–81 % for coagulated peat slurry. Peat slurry filtering can be performed on continuous vacuum filters of various designs including drum, disk, and plate.

3. Reducing moisture content in raw peat from 83–86 to 63 % by molding peat in a hydraulic press.

Thus, to optimize the process of peat slurry dehydration, a three-stage process should be combined within a single block of technological equipment located on board the platform.

3. Floating mining platform

The technologies for all-season extraction of raw peat need physical and mechanical optimizations of peat dehydration. The studies become even more relevant when it comes to the development of power-engineering mining equipment for the extraction and processing of raw peat materials from wetlands (RF Patent No. 2599117). This method involves the excavation of a mass of peat from a peat deposit, its dehydration, drying and compressing into sod peat directly at the extraction site, using mining equipment of a floating platform. The platform is fully or partially powered by the energy from burning the extracted peat materials.

The platform is fixed on a floating base with a motion mechanism. It houses technological autonomous modules for the hydraulic-enabled excavation and transportation of raw peat, its treatment,
pressing, drying, grinding, and stacking. Communication and power generating equipment is also located here [7, 10, 11].

4. Primary dehydration of peat

Peat slurry is dewatered in a filter press. Primary dehydration directly on board an autonomous mining and processing platform can dramatically reduce losses related to the removal of excess moisture entrained in peat. Thus reducing moisture content from 92 to 74 % leads to a four-fold reduction in the weight of raw peat, i.e. a loss of 75 kg of moisture from every 100 kg of extracted raw materials.

The need to study the rheological properties of peat subject to mechanical dehydration is due to their universal nature and ability to possess a wealth of information on the processes that occur in peat systems, both in natural conditions and at various stages of production, including technologically induced processes. They simultaneously accumulate and successfully display as a single unit, on the one hand, all structural attributes of peat, and on the other, some specific physical and mechanical properties of peat systems in the widest range of moisture contents [1].

Using a press for primary peat dehydration directly on board a mining and processing platform, it is worth paying close attention to the theory of dehydration to take place in a filter press. The filtration procedure is complex, since in most cases it is significantly affected by a sediment layer formed on the partition. In its turn, the sediment also takes part in the filtration, acting as an additional porous membrane. Hydraulic resistance in the filtering membrane practically does not change during the process (except for the cases when small particles are retained inside the pores). On the contrary, hydraulic resistance in the sediment rises as the latter becomes thicker. It is obvious that hydraulic resistance in the sediment at the beginning of the filtration process is zero due to its absence. Another criterion of sediments that affects the final value of hydraulic resistance is their ability or inability to change their porosity as the pressure increases.

The filtering process can run under various conditions, resulting in a number of modes:
- filtering at a constant pressure difference;
- filtering at a constant speed;
- filtering at variable pressure and speed [12, 13].

Filtering at a constant pressure difference is in line with the case study.

Analyzing the intensity of water separation during the mechanical extraction of peat pulp with a press filter, it is necessary to take into account the reactivity of peat components and the low strength of structures that determine the effectiveness of mechanical and physico-mechanical effects in order to control the rheological properties of peat systems.

To assess the compressibility of peat, the dependence of porosity on the pressure drop can be used. In logarithmic coordinates, the dependence is expressed by a straight line with a slope ratio characterizing compressibility. The compressibility of peat largely determines the type of dewatering equipment and service parameters. The lower the compressibility index (with equal resistivity), the greater the pressure for dehydration. Dehydration at optimum pressure makes it possible to achieve the most performance of a filter press.

The well-known numerous studies come to the conclusion that about 80 % of water held in natural peat can be removed by molding at pressures up to 2.0–2.5 MPa. A load increased up to 10 MPa and over has very little effect on the efficiency of mechanical peat dehydration, while high deformation velocity and specific filter loading of more than 0.2 g/cm² produce even a negative result. Provided that dewatering of peat takes longer, the amount of filtered liquid increases.

To calculate the amount of extracted moisture from peat pulp under the action of a press with a certain working load, it is necessary to calculate in advance the filtration area \( F_t \) (1) and the compaction area \( F_c \) (2).

\[
F_t = ab, \quad (1)\\
F_c = (a+2c)(d+2c) - ab, \quad (2)
\]

where \( a, b \) are work surface dimensions

where \( c \) is compaction width.
Next, an equation is drawn up to determine the required sealing force (3)

\[ P = Q_d + R_{or}, \]

where

\[ Q_d = pF_c, \]
\[ R_{or} = mpF_c, \]

where \( p \) is the main workload, \( m \) is the correction factor.

Taking into account (4) and (5), the authors obtain the equation of the sealing force in a general form (6):

\[ P = pF_t + mpF. \]

With the value of the maximum force \( P \) of the filter press, it is possible to find the amount of pressed moisture and optimize the process.

5. Conclusion

In order to optimize the process of moisture separation under the action of a load, it is necessary to conduct a series of experiments that will make it possible to reasonably select the parameters of a press for a dehydration module on board an autonomous mining and processing platform, and clarify the filtration coefficient for specific conditions. For this, a physical model was developed in the form of a cylindrical tank with a filtering bottom and an indenter piston to operate on a hydraulic press.

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