Modeling of the process of mechanical dehydration of raw peat materials in the working tools of mining machines

S L Ivanov, I N Khudyakova, E A Vagapova, and P V Ivanova

Saint Petersburg Mining University, 2, 21st Line, St Petersburg 199106, Russia

E-mail: irikhudyakova@yandex.ru

Abstract. The results of physical modeling of primary dehydration of raw peat materials of the disturbed structure in a thin layer and at excavator bucket digging directly from the watered deposit at peat quarry development are presented. The areas of rational application of mechanical moisture dehydration of raw peat materials are shown, which allow assessing the quality of extracted raw peat materials and products of its processing. By results of the carried out modeling of process of moisture reduction concrete recommendations on size of the basic parameters of working bodies of mining machines are given. In particular, the sizes of press pallets for a gravitational press of primary peat pulp dehydration are selected, the rational size of a column of pallets providing the set parameters of quality of a product of processing directly on board of quarry is revealed. Modeling was carried out and on its basis recommendations on selection of parameters and design of excavator bucket, for mining and primary dehydration of excavated raw peat materials of different compaction degree were given. The presented approximated curves of the dehydration process in the bucket allowed to clarify the parameters of the mining excavator bucket ensuring the specified quality of raw peat materials at the first stage of its extraction and processing.

1. Introduction

The current state of research on dehydration processes is characterized mainly by the intensification and improvement of existing equipment, the search for new highly effective methods of moisture removal and the creation of high-performance mining machines and apparatuses based on them [1, 2].

Moisture from raw peat materials can be removed in various ways: mechanical, gravitational, physical and chemical, thermal. For mechanical dehydration, the pressing is carried out in presses and in centrifuges. It is possible to separate free moisture from raw peat materials by mechanical means and achieve only 70% of peat moisture [3, 4, 5].

Since in the peat raw material by mass ratio at a moisture content equal to 90% for each part of absolutely dry peat there are nine corresponding parts of water, then after mechanical pressing to a moisture content of 80%, this same part of the dry substance will account for only four parts of water. Thus, reducing the moisture content of raw peat materials at the very beginning of its processing by only 10% corresponds to saving energy equivalent to the cost of evaporation of these five parts of water. And since mechanical dehydration is less energy-intensive, the use of such technologies can not only significantly reduce the energy consumption for bringing raw peat materials to standard values, but also reduce the time of this process [6, 7, 8, 9, 10].

In order to intensify the process of mechanical dehydration, various actions and techniques are used: drainage, treatment with electrolytes, wet charring, freezing, and electroosmosis. However,
many of them, due to technical difficulties, complexity of technological processes and high energy intensity, were unsuitable for industrial use [11, 12].

It is known that the main amount of moisture during mechanical pressing is removed in the first two minutes, and the dehydration process can be divided into two areas. The pressure range up to 2.0 MPa allows you to reduce the percentage of moisture from 90% to 80%. Dehydration peat to a moisture content below 80% requires a significant increase in pressure and energy consumption. An increase in pressure to 10 MPa or more has a negligible effect on the efficiency of the process of mechanical dehydration of peat, and at high deformation rates and specific filter loads of more than 0.2 g/cm$^2$, even a negative result is observed. Only with increasing duration of pressing increases the amount of filtered liquid. The application of high pressures with high deformation rates contributes to the rapid formation of dry peat layers in the filter, which leads to the locking of air and water inside the sample and the termination of filtration [13, 14].

2. Materials and methods - dehydration of water-peat pulp in a thin layer
To intensify the process of separating moisture under load the authors performed physical modeling of the process, allowing the first stage to clarify the regularities of changes in the filtration of moisture from water-peat pulp and based on the simulation results, implement informed choices of values of parameters of dehydration. The simulation was carried out on raw peat materials of the Zaozerskoye field № 1021.

Simulation of the process was carried out by compacting raw peat materials on a screw press in a cylindrical container, while the physical impact was carried out by a punch. The base of the container is perforated Rv 1.5-3 with a 23% perforation area. Figure 1 shows the simulation result in the form of graphs of changes in the average moisture of peat when pressure increases during pressing, depending on the ratio of the layer thickness of the pressed pulp to the layer thickness of the pressed pulp without holding under load, so curve 1 corresponds to the ratio of thicknesses equal to 5.37; curve 2-4.09; curve 3 – 3.16, respectively.

![Figure 1. Schedule of changes in the average moisture of peat from the pressure](image)

Figure 2 shows a graph of the intensity of changes in the layer thickness from pressure, the curve designations correspond to the designations of Figure 1.
Modeling of the process of peat dehydration in a gravity press allowed us to experimentally establish that it is advisable to squeeze peat in a thin layer at a load pressure of no more than 0.6 MPa. A further increase in the load does not lead to an intensification of the separation of moisture from the peat. Physical modeling allowed us to select the geometric parameters of the construction of pallets for the primary dehydration of peat pulp [15, 16]. The primary dehydration unit for peat pulp consists of vertical lifting and lowering wells, where pallets loaded with raw peat materials are lowered/lifted or emptied accordingly. Pallets made of structural investing, stacked on other pallets affect the downstream trays in the column of nested pallets, their weight and the weight of the material loaded therein, so lowering the moisture content of the molding raw material is carried out under pressure stacked on other pallets. Thus, the dimensions of the pallet 0.5x0.6x0.3 m with the height of the pallet column of 10.5 m for installation with a capacity of 10-12 t/h of raw peat materials with a moisture content of 70% were determined.

3. The study of primary dehydration of raw peat materials in the bucket

Six models of a cube-shaped bucket with different areas of perforation on its faces were created for simulation of primary mechanical dehydration of raw peat materials in the excavator bucket. Perforation parameters Rv 2-8 with a 32% perforation area. The bucket edge was 75 mm. On each face, the perforation was performed the same and took up half the area of the corresponding face. A bucket with a perforated single front face was mistaken for a base. The upper face in all buckets was missing and was replaced by a punch acting on the peat raw material loaded into the bucket model with an excess pressure of 0.02 MPa for thirty seconds. Each time 250±5 g of raw material was loaded. The latter was the peat raw material of the Zaozerskoye field № 1021, of medium disturbance, extracted by an excavator, with 92% moisture. The entire volume of raw materials used in the experiment was divided into three groups: № 1 is actually excavated raw material, № 2 is the same raw material, but pre-compacted, and № 3 is highly compacted peat raw material. In each series of experiments, equal-precision measurements of the initial bucket weights and corresponding measurements after pressing were performed. Thus, the loss of moisture during pre-pressing was estimated. The results of the processed experimental data are presented in Figure 3.

![Figure 2. Graph of the intensity of changes in the layer thickness from pressure, Hᵢ – thickness of the pressed pulp layer, h-thickness of the pressed pulp layer](image-url)
As can be seen from the figure, with increasing area of the perforated surface, the volume of pressed water increases, but the intensity of this increase allows us to conclude that the separation of moisture is only in a small layer in close proximity to the perforated wall. In depth, the sample practically does not change its moisture content. At the same time, the greatest effect of water separation occurs in the case of pressing of non-compacted material, when there are channels for the passage of the pressed moisture from the depth to the outer surface.

The trend lines of the approximated curves of the intensity of moisture separation during primary mechanical dehydration in the bucket have the form:

1. \[ m_{H2O} = 7.875e^{2.21Sper} \]
2. \[ m_{H2O} = 4.95e^{1.24 Sper} \]
3. \[ m_{H2O} = 2.4918e^{2.88 Sper} \]

This allows us to select both the shape and size of the excavator bucket.

4. Conclusion
As a result of physical modeling, it is established that the process of mechanical dehydration of raw peat materials in a gravity press is determined by the characteristics of pressure transfer in thin layers, which allows us to make a reasonable choice of geometric and power parameters of the design of the gravity press for dehydration peat pulp on board the quarry.

On the form of bucket – cuboid model of a bucket with perforations in its walls showed the effectiveness of the perforation at the stage of preliminary pressing in the excavation: with the increase in the number of perforated walls, and, accordingly, the area of the perforation, the process of dehumidification takes place with greater efficiency, however, if you change the shape of the bucket (e.g., with a rectangular base) thereby increasing the area of the bottom of the bucket and the number of perforations on it, it will contribute to the dehumidification by reducing the volume of raw peat is not adjacent to the perforated walls.

Also based on the simulation of primary mechanical dehydration in the bucket again shown the feasibility of squeezing in a bucket of raw peat materials of the damaged structures – this peat is the easiest to give off moisture, when the primary seal, and further processing can affect the quality of raw peat and products of its processing.

Figure 3. Graph of dependencies of water separation in peat depending on the bucket perforation.
References

[1] Goryachev V I, Mikheev I I, Yablonev A L and Fomin K V 2018 Choosing a press for dewatering peat in the technology of fractionation of peat raw materials by hydraulic washing Gorny information and analytical Bulletin (scientific and technical journal) 38 22-30.

[2] Lebedeva A I and Makarov S A 2018 The Problem of artificial dewatering of peat. Theoretical research and experimental development of students and postgraduates: collection of scientific papers. (Tver) pp. 136-140.

[3] Vagapova E A, Khudyakova I N and Ivanov S L 2018 On the issue of primary dewatering of peat raw materials extracted by hydro-mechanized method Socio-economic and environmental problems of mining, construction and energy: the 14th international conference on mining, construction and energy. (Tula: Tulsu Publishing house) pp 230-234.

[4] Rezvanova E A and Ivanov S L 2016 Intensification of primary dewatering of hydro-peat mixture in the extraction of peat raw materials on Board an Autonomous modular complex. Socio-economic and environmental problems of mining, construction and energy: 12th international conference on mining, construction and energy. (Tula: Tulsu Publishing house). p. 200-203.

[5] Sherstnev V I and Labzin M S 2017 Effect of water properties and structure of peat on the process of mechanical dewatering. Economic, environmental and social problems of the Ural mining industry.: collection of scientific articles (Yekaterinburg. Edited by N. V. Grevtsev And I. A. Koch.) pp 128-131.

[6] Kremcheev E A, Nagornov D O, Kremcheeva D A 2020 Changing hydraulic conductivity after rupturing native structure of peat under limited evaporation conditions. Lecture Notes in Earth System Sciences pp. 233-256. DOI: 10.1007/978-3-030-21614-6_14.

[7] Mikhailov A, Zhigulskaya A, Garmaev O 2019 An integrated approach to strip mining of peat. IOP Conference Series: Earth and Environmental Science 378(1) 012087 DOI: 10.1088/1755-1315/378/1/012087. pp.1-7.

[8] Mikhailov A V 2017 Open-pit mining of lignin waste storage Journal of Mining Institute 223 pp. 44-50. DOI: 10.18454/pmi.2017.1.44.

[9] Bondarev Yu Y and Ivanov S L 2014 Creation of equipment for mining and energy complex for the production of fuel from peat raw materials. Modern technologies in mining engineering: a collection of scientific papers of the seminar. (Moscow: MGSU). pp. 421-427.

[10] Goryachev V I 2012 Artificial dewatering of peat: monograph. TVSTU. (Tver) 183 p.

[11] Sherstnev V I and Usmanov A I 2018 Investigation of the influence of qualitative characteristics of peat on the dewatering process. Theory and practice of world science, no. 5. pp. 48-51.

[12] Sherstnev V I, Labzin M S, Resnick M A and Galembo A A 2017 Study of the processes of dehydration, taking into account changes of parameters of pressing. Ural mining school-regions: collection of reports of the international scientific and practical conference (Yekaterinburg). pp. 622-623.

[13] Vagapova E A, Khudyakova I N and Ivanov S.L 2019 Justification and selection of equipment for primary dewatering of peat raw materials during its hydro-mechanized extraction from an unsaturated deposit. Gorny information and analytical Bulletin (scientific and technical journal). No. 7 (special issue 18). (Moscow: Gornaya kniga Publishing house) p. 3-11. DOI: 10.25018 / 0236-1493-2019-3-4-3-15.

[14] Vagapova E A, Khudyakova I N and Fadeev DV 2019 Primary dehydration of peat on floating mining platforms. IOP Conference Series: Earth and Environmental Science (EES) 378 012104 DOI: 10.1088/1755-1315/378/1/012104. pp.1-6.