Preliminary study of tubular peat extrusion

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Abstract. This work describes the preparation and characterization of tubular peat granules for potential use in the field drying process, consisting of a mixed peat structure. Hollow peat tubes having internal diameter 30 mm and overall diameter 60 mm were produced by extrusion and used as a unit for the field drying process. The primary goal of this report is the development of the combination of fiber peat (top layer of deposit) with plastic peat (bottom layer of deposit) without additives and binders for producing a more stable and cohesive granule. The content of the mix was 1:5 by volume. When the moisture content was increased to 80% by mass (weight), moist pellets were formed. A simple test was performed on the peat samples to confirm the mixing efficiency. The advantage of such tubular geometry is that it provides 1.6 times higher surface area/volume for field drying process intensification. Promising results were achieved, in particular, when tubes with a bigger diameter were used. The method is inexpensive and simple to scale; however, further research is needed in view of a final optimization.

1. Introduction
Peat is generally regarded as a low-quality fuel source because of its high-water content in addition to lower fuel efficiency.

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 the Unified Soil Classification System (USCS), peat is a highly-organic soil. The highly-organic soils usually are very compressible [1].

The properties of peat vary from peatland to peatland and even from point to point in the same deposit. Fresh fibrous peat (acrotelm) tends to occur near the top of a deposit while the lower layers (catotelm) are frequently composed of soft, relatively dense and highly decayed material [2].

Removal of peat is the most commonly used procedure for peat excavation. The natural structure and properties of peat remain depending on an excavator way of production. Excavation of peat is made in the vertical direction practically throughout the whole depth of a deposit.

At vertical excavation layers of peat (plastic peat and fibrous) are mixing in a bucket of the excavator. Mixing of peat layers at excavation increases positive properties of the peat granules, such as stability during transport, high bulk density, low dust formation, etc.

Extrusion is a well-known and established peat shaping method. Extrusion is one of the most important materials forming processes due to its high productivity, lower cost. Many other tube-shaped products are formed through the extrusion processes. There are highly efficient, continuous and produces uniform products [3].

Peat is particularly interesting due to its excellent binding properties, which makes a combination with all materials possible for producing a more stable and cohesive granule.
The primary goal of this report is the development of the combination of fiber peat (top layer of deposit) with plastic peat (bottom layer of deposit) without additives and binders for producing a more stable and cohesive granule.

This work describes the preparation and characterization of tubular peat granules for potential use in peat field drying process, consisting of a mixed peat structure.

2. Materials and methods
The raw materials used in this study included peat samples from peat deposit Porsolovo, Leningrad region. In the Test Centre of Peat of All-Russian Research Institute of Peat Industry we carried out laboratory analyses for definition of Peat Botanical Content and Decomposition degree of peat by Standards [4] (Table 1).

| Depth  | Decomposition degree R, % von Post Scale | Botanical composition | Strength category | Humic acid/highly hydrolysable ratio HA/HH |
|--------|------------------------------------------|-----------------------|-------------------|------------------------------------------|
| 0-0.5 m| 5-10/H1 | Sphagnum magellanicum | 25 | low | >2.0 |
|        |        | Sphagnum angustifolium | 30 |                |                                          |
|        |        | Sphagnum majus         | 15 |                |                                          |
|        |        | Sphagnum balticum      | 10 |                |                                          |
|        |        | Sphagnum fuscom        | 10 |                |                                          |
|        |        | Scheuchzéria palustris | 10 |                |                                          |
| 2.5 m  | 25-28/H4 | Sphagnum magellanicum | 55 | high | <1.5 |
|        |        | Sphagnum angustifolium | 15 |                |                                          |
|        |        | Sphagnum majus         | 5  |                |                                          |
|        |        | Sphagnum balticum      | 5  |                |                                          |
|        |        | Cotton grass (Erióphorum vaginátum) | 10 |         |                                            |
|        |        | Bark and wood of pine  | 10 |                |                                          |

Why peat used as a bonding material is confirmed by the fact that peat contains a bitumen’s and humus that can be carried out as the bonding, besides, the peat itself is renewable energy source [5].

Extent of decomposition and botanical content considerably influence properties of peat therefore are used as universal indicators for calculation of parameters of technological processes of production and processing of peat raw materials. Organic binders act as viscosifier, plasticizer, lubricant and rheology modifier. The content of fiber peat (top layer of deposit) with plastic peat (bottom layer of deposit) mix was 1:5 by volume. Based on these conclusions, the table of peat samples on strength of granules (Table 2) was compiled.

The research was conducted under the following conditions. Product peat granules have a cylindrical form with diameter 60 mm and height 50 and 70 mm. Extrusion pressure was 40 MPa. In experiments on the piston press force of replacement of weight was registered as function of time and movement of the piston. The test of replacement lasted 10 seconds for steady formation.

The peat specimens were carefully mixed manually and placed in a plastic package for carrying out experiments on granulation. After preliminary separation we removed large wood inclusions from peat specimens. Preliminary dehydration of peat was conducted on a fabric filter press. Attrition of peat raw materials was conducted for the purpose of pre-machining on laboratory grinder [6]. The moisture content results for each sample are calculated in accordance with the relevant Standards for the standard oven method [7].

The blends of raw materials were then put into the piston press to produce the granules. Figure 1 presents the sketch of the extrusion assembly. Extrusion of peat was carried out on a piston press with a ram diameter of 32 mm and 300 mm long with a mandrel set. There is a direct hollow extrusion process...
in which a piston with a mandrel, presses peat through a die and creates a hollow component. Piston press was established by universal Zwick/Roell Z100 Machine. Breakdown of mix is via dies with a length of calibrating part of 80 mm and with a diameter of 60 mm at a speed of 0.0125 m/s and ambient temperature ±20 °C.

The extruded hollow granules were dried (40 °C) to the desired moisture (25 %) in an oven with air circulation. Air temperature in a drying chamber was taken by the thermometer with an accuracy of ±1 °C. Experiments on drying were made with the relative air humidity of 30 % and atmospheric pressure of 758 mm of mercury column and air temperature of +23 °C. Wet granules were stored in a cartridge that was suspended in the drying chamber at the height of 100 mm from an output nozzle of a fan heater. The area of a cartridge is 0.08 m².

The weight of granules before densification and the weight of container are determined on a laboratory scales of VLKT-500 on accuracy ± 0.01 g.

![Figure 1. Sketch of the extrusion assembly.](image1)

![Figure 2. Experimental tubular peat granules.](image2)

Figure 1. Sketch of the extrusion assembly.

Figure 2. Experimental tubular peat granules $L_1=70$ mm; $L_2=50$ mm; $\Phi_{\text{overall}}=60$ mm; $\Phi_{\text{internal}}=30$ mm

Recording of the loading operating on a specimen and the deformation arising thus was conducted in the automatic mode. The validation of physic, mechanical properties of granules determined the sizes, density, and durability in accordance with the Russian Standard [9].

3. The evaluation studies

Based on the theory of bonding, the force of bonding represents the sum of physical and mechanical bondings. This is generally a mechanical bonding and results of mechanical connection when the bonding substance enters an internal cavity of the bonding substance [10]. Peat as a bonding substance has to be used in such ways for processing of natural high-polymeric organic initial raw materials. High superficial activity of peat is lowered by tension and a strong dispersive ability.

Small colloidal particles of peat facilitate the process of granules densification. Due to group factors, the composition of peat, humic acids (HA) and high-hydrolyzed (HH) acids exert the greatest influence on durability of hollow granules of peat (Figure 2) [11].

In the process, a mixture of peat components is extruded into granules, which are dried and consolidated to a strong form. The key element in the process is peat which consists of bitumen, humus, cellulose fibers and lignin. These components impart special characteristics to peat used for bonding materials. The main functional parts in humic substances, including bitumen, humic acids and fulvic acids, could provide sufficient strength for the wet and dry granules [12].

The percent of humic acids is higher than 15 % and that of bitumen is more than 3-4 %, which increases the inhibiting and consolidating abilities of peat bonding. Strengthening of rheological, structural and mechanical properties of the mix is observed. Extruded peat consists of fragmented
particles, but in the granules, it is added using compression in the press, which is shown in density (Table 2) [13].

Dry material appearance refers to the character of the dried hollow peat granules: these are good granules that are well formed, their surface is smooth. The quality of hollow peat granules refers to the characteristics that can be tested; they are density or strength. The results of the quality test for granules produced in this series are discussed below. Hollow granules were characterized using tests associated with the storage, handling and transport of granules [14].

Granules quality in the lab tests was evaluated by measurements of the dry granules diameter (shrinkage), density and durability when dropped from a height to a concrete pad.

As shown in Table 2, variations in the dried granules diameter from 60 mm to 40-42 mm are indicating that drying shrinkage of the granules is significant.

Granules density is mostly in the range from 873 to 914 kg/m³. The density of coal is 1364 kg/m³. The jointing and density, which in turn depend on the extent of mechanical processing of material, and also technological indicators of processes of formation and drying, have an essential impact on strength properties of granules. Table 2 shows the parameters of tubular peat cylindrical granules.

Unit density, which affects floatability of extrudates, is a very important quality parameter for intensification of the drying process in the peat field. Higher density means lower porosity and lower water adsorption of tubular peat granules.

Volume shrinkage of usual peat granules after drying makes 50-60 % [8]. Volume shrinkage of tubular peat granules after drying makes >70 %.

Experiments on mechanical strength of tubular peat granules were made by drop shock testing, which is defined as the acceleration experienced by an object dropped onto a hard surface. Granules could be dropped from a height of 2.0 m on a concrete floor and survive [14]. The mechanical strength of tubular peat cylindrical granules made 92.3 %.

Drop shock testing is defined as the acceleration experienced by an object dropped onto a hard surface.

Table 2. Parameters of tubular peat granules

| Sample          | Average (wet granules, wₚ=80.4 %) | Average (dry granules, wₚ=24.4 %) |
|-----------------|-----------------------------------|-----------------------------------|
| hollow peat     | Average volume, m³⋅10⁻⁴ mass, kg  | Average Øexternal, mm Øinternal, mm length, mm mass, kg volume, m³⋅10⁻⁵ density, kg/m³ volume shrinkage, % |
| L=50 mm         | 1.06 0.102 40.1 21.9 30.7 0.0264 2.89 913.5 72.7 |
| L=70 mm         | 1.48 0.143 42.2 22.3 42.2 0.0371 4.25 872.9 71.3 |

The surface area/volume ratio for the straight cylinder is 0.160 while the surface area/volume ratio for the hollow straight cylinder is 0.170. The advantage of such tubular geometry is that it provides a 1.6-time higher surface area/volume for the field drying process.

A number of other benefits include ease of manufacturing using extrusion and dimensional stability under temperature and oxygen activity gradients [15].

4. Conclusion
This research was focused on the evaluation of the preliminary study of hollow peat granulation. Fuel granules were prepared using fiber peat and plastic peat as main components. The content of the mix was 1:5 by volume. The organic functional components in peat were chemically adsorbed onto the surfaces of fiber particles to improve the granules strength.

Thus, the conducted preliminary research showed prospects of the method of peat hollow granulation. The advantage of such tubular geometry is that it provides a 1.6 time higher surface area/volume for the field drying process. This information can be applied to a more practical approach where real extrusion process parameters can be established.
Ultimately, production of hollow peat tubes on a larger extruder may change the interactions observed in this study, but we have examined a feasibility study of tubular peat extrusion, which will be useful for scale-up purposes.

Further study is being undertaken to analyze hollow peat granules in evaluating the water resistance defined as the time required for fuel destruction and dispersion in the water medium.

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