

Justification of Screw Press Rational Parameters and its Working Modes during Sod Peat Extraction by Milling-forming Method

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Abstract. Sod peat production involves the use of screw press machines. Although the designs of such machines differ in details, they have a number of similar parameters including the highest power intensity throughout the entire production cycle. Sod peat forming conditions are investigated in order to reduce the process energy intensity without losing sod density and, therefore, strength. Laboratory experimental dispersion and moulding of peat are done with a screw press having five speeds, three interchangeable nozzles and two screws with different step of turns. The moisture of the feedstock, the effective power and capacity of the press, the specific energy of the process are determined. The findings show that the most rational operating modes of a screw press consist in the blend of screw rotation speed, nozzle diameter and step of screw turns.

1 Introduction

Peat extraction by milling-forming method is intended to eliminate the shortage of household fuel in the areas where there is no local gas available. Peat reserves in Russia are huge and, according to the most conservative estimates, make up about 35 % of the global ones. Today peat makes up a significant part of the local energy balance in some regions, and its combustion carried out in modern fluidized bed boiler plants is highly profitable and competitive compared to imported coal, fuel oil and even above-limit gas [1, 2]. It is light (bulk density being up to 500 kg/m³) and safe fuel with a calorific value of 3200 Kcal/kg and a moisture content of 33 %. The situation when local renewable are used because of riding gas costs is similar in other countries of the world [3–5].

The milling-forming method consists in the application of a machine mounted, trailed or semi-mounted on a wheeled tractor. The machine mills slots in a peat deposit to the depth of 550 mm, forms peat in a screw press and spreads sods through a multi-flow nozzle on a field in the form of cylinders or waves for later natural drying. Slot milling and forming are the most energy-intensive operations (about 50 % of operating costs and about 25 % of the total production cost) in the entire technological cycle of peat production [6]. Considering the stated and the fact that at present Russia is designing various improvements of milling

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machines [7], this research seems to be relevant to find ways to reduce the energy intensity of dispersing and forming peat without losing strength characteristics.

As numerous investigations have shown high-moor peat is the best in terms of formability and its initial moisture content w and degree of decomposition R must be in the intervals $w = 82\text{--}84\%$; $R = 25\text{--}35\%$ [8]. But the issues concerning the modes of forming have been insufficiently studied yet. The issues are screw rotation speed, a step of screw turns, a ratio of the flow section area of a stand-pipe to that of a nozzle.

2 Method used

In order to solve the above mentioned problems a laboratory experiment was conducted to form complex high-moor peat having the degree of decomposition $R = 25\text{--}30\%$ and the average moisture content $w = 83.44\%$ determined by a standard procedure of drying a peat sample and with the use of a moisture analyzer. Since a milling-forming machine crushes peat during its excavation from the deposit before it enters a screw press, test samples of peat feedstock were pre-crushed by dispersing additionally, with wood inclusions being screened. The forming was carried out with a laboratory facility (fig. 1).

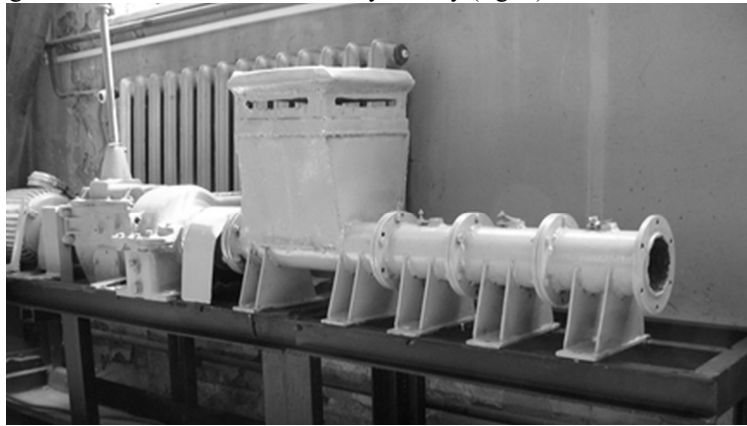


Fig. 1. Laboratory screw press.

An induction 10 kW AC electric motor with a rotor speed of 1480 RPM, a 5-speed gearbox and a cylindrical gear with a gear ratio of $i = 4.25$ allowed the screw rotational speed to range from 55.81 to 429.86 RPM. The press was stocked with three nozzles of 52, 60 and 92 mm internal diameters and two screws with a step of turns $S = 50$ and 110 mm (fig. 2).

During the experiments the operation of a screw press was tested in idle and load conditions in five modes corresponding to five different gearbox positions. The power required to drive the press at idle and under load (N_{id} and N , kW, respectively) was calculated by dependences:

$$N_{id} = \frac{3UI_{xx}\cos\varphi}{1000}, \quad (1)$$

$$N = \frac{3UI\cos\varphi}{1000}, \quad (2)$$

where U is voltage in one of the motor phases, V; I is current in one of the motor phases, A; $\cos\varphi$ is an induction motor power factor equal to the ratio of active power N , kW, necessary to do network and avoid mechanical losses, to gross power consumed by an electric motor (for the motor installed on a screw press $\cos\varphi=0.88$).

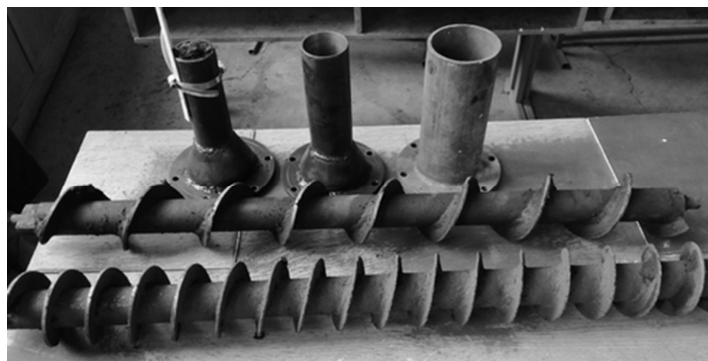


Fig. 2. Interchangeable nozzles and screws for press.

Network N_u , kW, was determined as the difference between gross power and idle power:

$$N_u = N - N_{id} . \quad (3)$$

The rate of formed peat output from a nozzle v , m/s, was estimated by a pattern adjusted to it, its length being $L = 0.15$ m, and with a stopwatch (fig. 3).



Fig. 3. Peat forming process.

Press performance Q , m³/s, was calculated with the formula:

$$Q = v \frac{\pi d^2}{4} , \quad (4)$$

where d is a diameter of the installed nozzle, m.

The power intensity of dispersion and forming A , J/m³ was calculated by the ratio:

$$A = \frac{N_u}{Q} . \quad (5)$$

When formed in different modes the peat sods were sorted out in special ditches and dried in the shadow mode for 25 days to achieve an average moisture content $w = 23.12$ % which is close to the equilibrium one. After they were dried with the volumetric method, the density of the sods obtained in different modes was estimated with a digital caliper (0.01 mm accuracy) and “Acom JW-1” scales (0.1 g accuracy). All the experiments were repeated six times.

3 Results and discussion

After doing the calculations and their analysis and screening the outliers, the energy intensity-vs-screw rotation speed curves were made for different installed nozzles of diameter d and screws with step of turns S (fig. 4, 5).

One of the other ways to manage energy intensity in the production process is simply to change the number and size of nozzles. Considering the fact that the pressure is created by the screw in the stand-pipe and increases in the nozzle facing back pressure [9, 10], we propose to introduce the concept of “head coefficient” k_H to describe the peat consolidation degree under different conditions and to use the method of geometric similarity. The head coefficient is the ratio of the flow area of a stand-pipe to those of nozzles:

$$k_H = \frac{D^2 - d_{sc}^2}{md^2}, \quad (6)$$

where D is a stand-pipe internal diameter; d_{sc} is a pipe outer diameter being the base for a screw flight; d is a nozzle diameter; m is the number of nozzles.

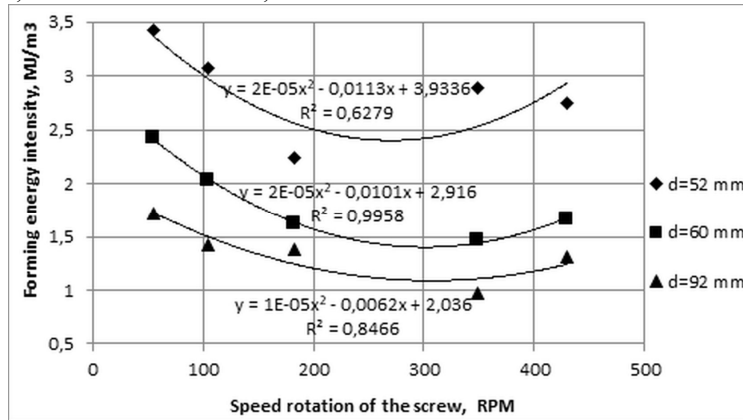


Fig. 4. The dependence of the sod peat energy intensity upon speed rotation of the screw with step turns $S=110$ mm.

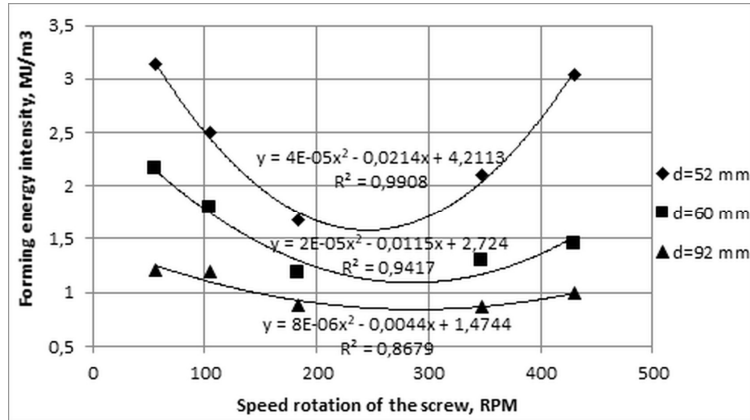


Fig. 5. The dependence of the sod peat energy intensity upon speed rotation of the screw with step turns $S=50$ mm.

A screw press with $D=102$ mm, $d_{sc}=49$ mm was used. In this case the head coefficients k_H were 2.96, 2.22, and 0.95 for nozzles with 52, 60, and 92 mm diameters respectively.

The valuation of sod densities when average moisture content makes up 23.12 % showed that the density depends on the screw speed and varies according to a logarithmic law (fig. 6, 7). Regression equations with coefficients of determination R^2 are obtained for all the dependences presented.

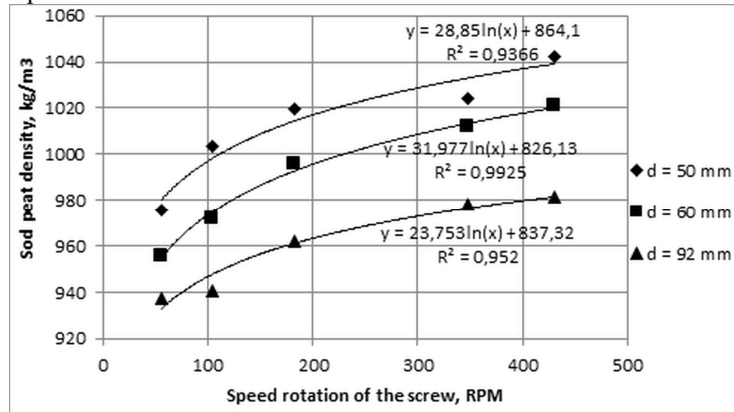


Fig. 6. Sod peat density dependence of rotation frequency of the screw with step turns $S = 110$ mm.

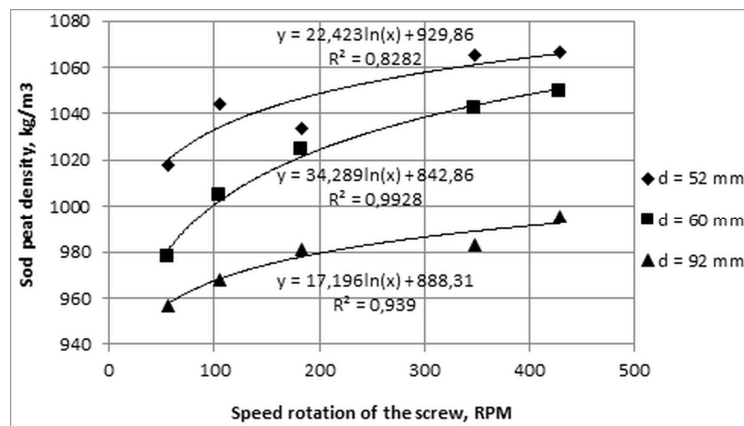


Fig. 7. Sod peat density dependence of rotation frequency of the screw with step turns $S = 50$ mm.

It is evident that lower energy intensity of forming gives greater density of peat sods obtained with a screw having a pitch of turns $S = 50$ mm.

4 Conclusion

With the energy intensity of the forming being minimal at the screw rotation speed of 220–320 RPM, a diagram of the final sod peat density-vs-forming energy intensity is built for the speed of 270 RPM (fig. 8).

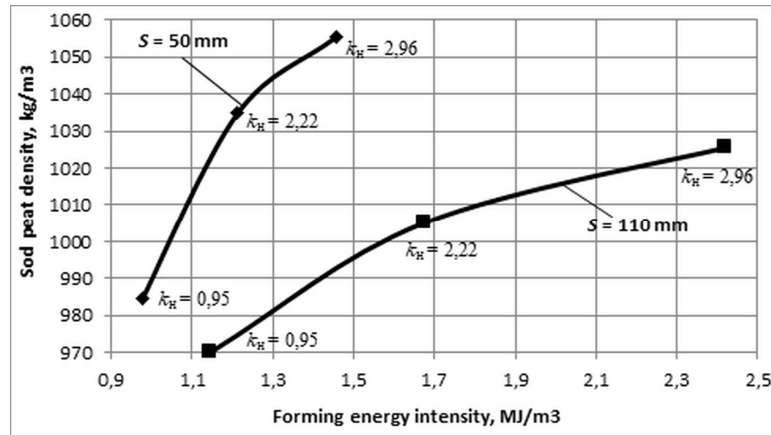


Fig. 8. Sod peat density dependence of energy intensity at a rotation speed of screw $n = 270$ RPM.

As follows from the obtained dependence, when energy intensity increases, the sod density growth intensity drops significantly with a change in k_H from 2.22 to 2.96. Therefore, forming with a head pressure coefficient $k_H = 2.22$ can be considered a rational mode.

5 Inferences

The intensity of productivity development is higher than the growth rate of the power required to produce a sod with a certain screw rotation speed. When the speed is higher, an unsteady feedstock movement begins (particles stop moving only in the axial direction and begin to rotate with the screw). This leads to a change in the productivity and power growth intensity and results in the increase of the process energy intensity. It is evident that lower power consumption and greater sod density, achieved with a screw having a 50 mm step, helps the machine operate in an efficient mode. Therefore, the step of the screw turns should be close to half of the outer diameter of the screw. The most efficient mode seems to be the screw rotation speed $n = 220\text{--}320$ RPM with the head coefficient $k_H = 2.22$ and screw turn step $S = 0.5D$. Designing and using milling-forming machines in efficient modes will reduce the loss of peat during production [11] and reduce the specific energy consumption without losing the sod density and, consequently, strength.

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