Technical Modernization as an Element of Technological Safety of a Peat Mining Enterprise (for Example «Tverregiontorf»)

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Abstract. In the study, the authors analyze the structure of the peat mining equipment park of «Tverregiontorf» and assess the technical level of the machines used, which affects the dynamics of peat extraction volumes. The article deals with the problem of assessing the technological safety of peat mining equipment. The existing two approaches to the analysis of technological safety are not adequate enough. The authors propose to use a technical and economic approach to the analysis of the level of technical safety of a peat mining enterprise on the basis of a model of functioning of a peat mining machine. The functional model of peat technology is based on the idea of technical modernization of the peat machine design and modernization of peat production technology. The technical and economic approach makes it possible to determine the optimal structure of the mining equipment park, as well as to modernize the technology of the production process of peat extraction and to form appropriate mobile sets of machines for the extraction of peat and peat-wood raw materials.

1. Introduction

In modern conditions of economic development, peat production is in a crisis, decline and depression. The volume of peat extraction fell sharply back in 2000 and so far there has been no growth in industrial production. It should be noted that this industry in Russia has always been unprofitable, and until now the issue of increasing its economic security is very relevant. In the Tver region, out of 5 enterprises representing the peat extraction industry, only one is functioning as operating – «Tverregiontorf». The main and most of the extracted peat is used as an energy resource in the fuel balance at regional thermal power plants.

Modern conditions of economic development impose stringent requirements on the technologies and technological equipment of peat production, which affects their technological safety. In the interpretation of the authors, the technological safety of a peat-mining enterprise is a complex concept that includes optimization of the structure of a fleet of technological equipment, an assessment of the technical condition of a fleet of equipment, the choice of an optimal strategy for service support of
peat-mining machines and equipment, as well as an assessment of the level of innovativeness of the equipment used [1-5].

For the effective operation of a peat mining enterprise, it is necessary to monitor the state of its material and technical base, namely, technological equipment and production technology. The technological safety of a peat mining enterprise involves the creation and use of such a technical base, technologies and business processes that enhance the competitiveness of peat production. If the structure of the park of technological equipment is characterized by a high percentage of wear and tear, both physical and moral, and a low rate of equipment renewal, then a peat mining enterprise has a sharp increase in the risk of not fulfilling the extraction program and failures in the operation of mining machines due to their frequent breakdowns. At the same time, in order to increase the level of technological and economic security, the outdated technologies for the development of a peat deposit used by a peat mining enterprise must meet modern requirements, which imply flexibility, mobility and independence from mining and geological and unfavorable weather conditions of the peat mining season.

2. Theoretical approaches to the concept of «technological safety»

At present, the Russian scientific community is only beginning to gain interest in methods for assessing and analyzing the technological safety of industrial machines. There are two points of view on this issue. Most researchers adhere to the classical, engineering approach, which assesses the technical condition of machines in terms of reliability, durability and maintainability. The term «technological safety» appeared at the intersection of technical and economic sciences. It is mainly used by economists when analyzing the level of use of a fleet of technological equipment at various enterprises and the adopted system of service support [6-11].

At the same time, the assessment of the impact of technological modernization of peat mining equipment on the technological safety of an enterprise in the peat industry remains poorly studied. In addition, the peat extraction technologies themselves also require modernization. From an engineering point of view, the technological safety of machines (Figure 1) is a system of measures to ensure the safe operation of a machine throughout its useful life. From a technical and economic point of view, technological safety (Figure 2) is an element of the economic security of an enterprise, providing a continuous, uninterrupted, rhythmic, profitable production process. This element at a mining enterprise consists of two parts: the technological safety of the mining equipment fleet and the technological safety of the mining technology used.

![Figure 1. Technological modernization in the structure of technological safety of peat production (engineering approach).](image)

The factors of technological safety of a peat-mining enterprise are directly determined by the sphere of its production and economic activity. The goals and objectives of a particular enterprise create priority areas for ensuring the technological safety of the enterprise. Thus, the authors present the technological safety of a peat enterprise as a complex function:
where $f_3$ - is the function of environmental friendliness of production ($A, W, L$ - the volume of emissions of pollutants into the atmosphere, water and land); $f_{TC}$ - is the function of the technical condition of the vehicle fleet ($SP$ - the structure of the vehicle fleet,%; $MRO$ - the effectiveness of repair strategies,%; $EM$ - equipment modernization,%); $f_{TD}$ - function of peat extraction technology ($MTO$ - modernization of technological operations,%; $O$ - optimization of extraction technologies,%; $EP$ - efficiency of organizational and production processes,%).

As Figure 2 shows, the technical and economic approach to the concept of «technological safety» is much broader. However, due to limitations in the scope of the article, the authors decided to focus on the study of the technical modernization of peat mining machines and its impact on the technological safety of the enterprise.

![Figure 2](image)

**Figure 2.** Technological modernization in the structure of technological safety of peat production (compiled by the authors).

3. **Model for assessing the «technological safety» of peat mining machines**

To assess the level of technological safety of peat mining equipment, the authors propose to use a technical and economic model of a mining machine (Figure 3).

![Figure 3](image)

**Figure 3.** Technical and economic model of the peat mining machine (compiled by the authors).

Technical modernization of peat mining equipment is aimed at improving the quality properties of the machine, that is, the changes made to the machine design must ensure reliability, reliability, high productivity, maintainability [12-16]. The quality of the construction of a peat machine depends on the materials and technologies used in its creation. In turn, the quality characteristics of the machine are influenced by the external operating conditions of the equipment and the requirements imposed by the mining technology used. In this regard, in order to ensure the safe and efficient operation of mining
equipment, its high-quality service support is necessary. The technical and economic model of the operation of the peat mining machine made it possible to develop an economic model of the life of peat mining equipment to optimize the structure of the park of technological machines of «Tverregiontorf», taking into account the requirements of the peat mining technology used and the market situation [17]. Thus, technological safety is associated with operating costs for the operation of peat mining equipment and its technical modernization, as well as with the volume of peat extraction (productivity) [18 - 20].

Operating costs for the maintenance and servicing of a peat mining machine include: the cost of service support, spare parts, equipment rental, the cost of upgrading machines, that is, the costs necessary to ensure the operable state of peat mining equipment during the entire useful life. Costs depend on the method and type of peat extraction technology used and the maintenance strategy adopted. Income from the use of peat mining equipment is provided by the number of productive machine-hours of equipment operation in the operations of the peat mining cycle. The more time the peat mining equipment works, the more efficiently the favorable days of the peat mining season are used and the opportunity arises to increase the production of peat, since the equipment works without downtime. Thus, the technical and economic model for assessing the technological safety of a peat mining enterprise will look like:

\[ TS = \frac{P}{OC} \cdot 100\% \rightarrow \text{max}, \]  

(2)

where \( P \) - is the profit from the operation of peat mining equipment, rubles; \( OC \) - operating costs for the operation of peat mining equipment, rubles.

Graphical interpretation of model (2) is shown in Figure 4.

![Figure 4. Model for determining the technological safety of peat mining machines.](image-url)

4. Discussion of the received data

For 5 years, the authors conducted observations of the technological state of the peat-mining equipment park of the «Tverregiontorf», the results of which are presented in (Table 1).

| Indicators                        | 2015 | 2016 | 2017 | 2018 | 2019 |
|----------------------------------|------|------|------|------|------|
| Peat extraction, th. t           | 0.4  | 1.4  | 0.8  | 1.2  | 1.2  |
| Coefficient equipment readiness, un. | 0.58 | 0.58 | 0.78 | 0.8  | 0.81 |
| Structural complexity coefficient, un. | 0.5  | 0.5  | 1.0  | 1.2  | 1.2  |
| Depreciation rate, un.           | 0.9  | 0.9  | 0.8  | 0.75 | 0.75 |
| Technological profitability, %   | 10   | 10   | 13   | 15   | 17   |

The analysis of the data in Table 1, as well as the economic and technical reporting carried out by the authors, showed that «Tverregiontorf» is in crisis. At the same time, the dynamics of production
volumes depends to a large extent on the state of technological equipment and weather conditions of the production season. For a complex of peat mining equipment with a service life of 15 years, according to Table 1 shows the coefficients of technical readiness and constructive complexity using the reporting data of the enterprise from 2015-2016, which are 0.58 and 0.5, respectively. According to the authors, such a readiness factor of equipment is unacceptable, and a further increase in the level of readiness of peat mining machines is possible when the structure of the technological park is updated to similar ones, or to machines of higher structural and technical complexity that meet the requirements of peat extraction technology.

The availability factor is influenced not only by the design parameters of equipment reliability, but also by the effectiveness of the adopted service strategy and even the adopted peat extraction technology. For this reason, starting in 2017, the authors modernized the technological process of peat extraction at the studied enterprise. The main disadvantage of the peat extraction technology used is the strong dependence on the weather conditions of the extraction season. Therefore, for the efficient use of favorable (rainless and calm) days of the production season and timely response to the changing market conditions, it is necessary that the technology is adaptable and flexible. In this regard, it is necessary to optimize the structure of the park of technological machines in the direction of increasing the share of mobile technological complexes for peat extraction. In view of this, a technical modernization strategy was developed for the park of technological machines for peat extraction at the «Tverregiontorf», which consisted in solving the following tasks:
1. Improvement of the structure of the park of technological machines and equipment;
2. Improvement of the applied strategies of technical support of peat mining machines;
3. Modernization of technology and technological operations of peat extraction;
4. Use of universal, mobile technological complexes for peat extraction.

To solve the first problem, the authors have developed a catalog of peat equipment used at the peat enterprise «Tverregiontorf». The result of solving this problem was an automated procedure for analyzing the structure of the peat enterprise technological equipment park, assessing the level of equipment wear, capital productivity and the rate of renewal of the «Tverregiontorf» machine park. The result of solving the second problem makes it possible to automate the repair management system, assess the cost of repairs and the level of equipment readiness for the peat production season. For the conditions of «Tverregiontorf» it was proposed to use the following options for mobile systems: using an excavator, a loader, harvesting equipment; using a milling rotor, loader, harvesting equipment. The indicators of technological safety of methods of peat extraction using mobile complexes are presented in Table 2.

Table 2. Indicators of technological safety for 2019.

| Indicators                                      | Technology №1 | Technology №2 |
|------------------------------------------------|---------------|---------------|
| Return on assets ratio, un.                    | 1.3           | 1.8           |
| Structural complexity coefficient, un.         | 1.1           | 1.3           |
| Coefficient of innovation, un.                 | 0.8           | 1.2           |
| Share of repair and maintenance costs, un.     | 0.50          | 0.45          |
| Availability ratio, un.                        | 0.75          | 0.88          |
| The number of machine-h for the production season | 100           | 120           |
| Peat extraction, t                             | 0.52          | 0.68          |
| Technological profitability, %                 | 7             | 10            |

5. Conclusion
Analysis of the structure of the company's mining equipment park, the used repair strategies and the effectiveness of the used peat extraction technologies made it possible to assert the following:
1. After the modernization of technological equipment, carried out since 2017, the indicators of technological safety have a positive growth trend (Table 1).

2. Technological safety is assessed using the indicator of technological profitability (profitability of the machine used), which takes into account the effectiveness of the adopted repair strategy, high-quality structural and production characteristics of the machines used.

3. Requirements of peat extraction technology make it possible to formulate a technical task in the areas of modernization of mining equipment.

4. The unpredictable variability of the market conditions for conducting production activities in the peat industry forces enterprises to modernize both the peat extraction technology and technological equipment, which in turn makes it possible to assess the level of innovativeness of peat mining machines and the direction of their modernization in the course of repair work.

5. Increasing the level of organization of production implies the organization of business processes for the production of peat products of a full cycle, from the technology of extraction of peat raw materials and technology of production of peat products for various purposes, ending with the organization of sales processes and delivery of finished peat products to the consumer.

If it is necessary to respond quickly to changing market demands, namely to increase or decrease the volume of peat extraction and the range of peat products, the authors suggest using mobile technological complexes (MTC). In addition, in order to increase the flexibility and adaptability of the peat mining enterprise to the weather conditions of the season, modernization is being carried out in the process of repairing peat machines. The equipment is being modernized in the direction of improving the chassis and increasing the cross-country ability of the equipment in the event of a rainy mining season, or in the direction of reducing the cost of maintenance and repair, as well as increasing the productivity and reliability of peat mining machines or their structural elements.

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