Technological process and laws of change of energy consumption parameters of spinning enterprises

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Abstract. Textile industrial enterprises are composed of three main sectors, which differ significantly from each other in terms of energy capacity, and include - spinning, weaving and finishing departments. In comparison to other departments, spinning technological processes consumes the most electricity. It is necessary to use modern energy-saving devices and to improve technological processes in accordance with the requirements of the times. Building an energy balance based on the analysis of the enterprise's technological processes, as well as forecasting electricity consumption, is one of the urgent issues. In this article, the issues of energy saving and efficiency improvement and forecasting in spinning departments are considered.

1. Introduction

Today, the issues of rational use of energy resources and improvement of energy efficiency are one of the urgent problems for mankind. In the developed countries of the world, textile enterprises are improving more and more. This industry itself consists of complex and diverse branches, one of the largest branches of which is yarn production. The state of electricity consumption of textile enterprises of the republic in 2023 was analyzed (Fig. 1).

![Fig. 1. Electricity in textile enterprises consumption situation in 2023](image)

The analysis of electricity consumption in the case of the textile industry in Figure 1 illustrates that the majority of electricity is spent in the spinning section. For this reason, analysis and improvement of the efficiency of electricity consumption in spinning enterprises is one of the important issues.

The most promising ways to reduce the relative consumption of electricity in spinning enterprises include:
- creation and modernization of technological equipment based on a fundamentally new design;
- reduction of technological transitions;
- usage of optimal loading parameters of equipment;
- introduction of high-speed pneumatic machines;
- installation of high-efficiency light sources.

At the same time, the main features of spinning production include:

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- multi-stage production;
- the presence of periodic interruptions in the work of machines to remove accumulated products;
- breaks in work to eliminate thread breaks [1, 2].

The rational use of electricity in spinning enterprises is largely determined by technological factors, as it helps to reduce production costs while increasing production, improving quality and reducing energy consumption. It is necessary to determine reserves of electricity and heat energy savings in enterprises and associations, reduce losses in electricity and heat networks, rationalize technological processes, introduce new technology and modernize existing equipment, in the direction of more complete use of low-potential energy. It is also necessary to improve control over the rational use of electricity and heat energy [3].

The main energy resource consuming departments of spinning enterprises are as follows:
- technology (equipment procedures, spinning processes);
- ventilation (ventilation system);
- heating;
- lighting;
- auxiliary needs (Table 1).

Fig. 2. Technological scheme of the enterprise “WBM POMITEX DIROMM” LLC
Table 1. Departments of the enterprise “WBM POMITEX DIROMM” LLC, where the main energy resources are consumed

<table>
<thead>
<tr>
<th>Departments of the enterprise</th>
<th>In the consumption of general energy resources share, %</th>
<th>Power consumption, kWh</th>
<th>In relation to the total power of consumption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology (including mechanization)</td>
<td>Electricity</td>
<td>Thermal Energy</td>
<td>60,0</td>
</tr>
<tr>
<td>Including electrical technology</td>
<td>2,0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Heating and ventilation</td>
<td>13,9</td>
<td>28,5</td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>14,3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Auxiliary needs</td>
<td>8,8</td>
<td>1,5</td>
<td></td>
</tr>
</tbody>
</table>

From the information presented in Table 1, it can be seen that this technology is the part of the spinning enterprise where the main energy resources are consumed [9].

The technological process of a spinning enterprise consists of a complex process, and the relationship between the elements of the technological process is determined by internal and external factors. The spinning enterprise “WBM POMITEX DIROMM” LLC, which is considered the object of the research, is an enterprise that produces high-quality cotton yarn products that meet world standards, and consists of 2 blocks A and B. Block A is now fully operational.

Figure 2 illustrates the sequence of technological processes of the spinning enterprise “WBM POMITEX DIROMM” LLC. The technological scheme covers the processes from bringing raw materials, i.e. cotton fibers, to the state of the finished product.

The spinning shop has 30 Saurer Zr72XL machines, each machine has 1,628 miles. Up to 350 kg of product is produced in one shift. After that, the coils of wound threads are sent to the rewinding machine using a transport system. The task of the rewinding machine is to identify defects in the wound threads and eliminate them. Prepared semi-finished products are sent to packaging shops. The working mode of the enterprise is a continuous production enterprise, and it operates in three shifts per day. 1200-1700 kg of products are produced in one shift. The enterprise mainly produces different brands of cotton thread products of the same weight (2.4 kg):
- Ne 30/1 is 125,000 meters long;
- Ne 28/1 is 115,000 meters long;
- Ne 24/1 is 98,000 meters long.

2. Research Methods

The enterprise consumes 2.5 million kWh of electricity per month. This corresponds to an average annual consumption of 20.2 million kWh of electricity. Today, the calculation and control of the electricity consumed by the enterprise is carried out with the help of modern electronic meters. It also pays for the consumed electricity on the basis of a differentiated definition.

At the enterprise, technical re-equipment is constantly carried out, as well as technical operation works are carried out constantly. As a result, it allows to increase the quality of products in the production process.

The share of electricity consumption in the production process of the spinning enterprise is analyzed based on the data of Table 2 [7].

Table 2. Information on the power of consumption of the “WBM POMITEX DIROMM” LLC enterprise by shops in 2022-2023

<table>
<thead>
<tr>
<th>The name of the workshops</th>
<th>2022</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power consumption, kWh</td>
<td>In relation to the total power of consumption, %</td>
</tr>
<tr>
<td>Shake and bite workshops</td>
<td>109,29</td>
<td>3</td>
</tr>
<tr>
<td>Flattening shop</td>
<td>171,22</td>
<td>5</td>
</tr>
<tr>
<td>Wrap shop</td>
<td>218,57</td>
<td>6</td>
</tr>
<tr>
<td>Spinning shop</td>
<td>2768,57</td>
<td>76</td>
</tr>
<tr>
<td>Lighting and other auxiliary needs</td>
<td>291,43</td>
<td>8</td>
</tr>
<tr>
<td>Total:</td>
<td>3559,08</td>
<td>100</td>
</tr>
</tbody>
</table>

Based on the analysis in Table 2, it was found that the main electricity consumption of the enterprise is spent on technological processes. By 2022, electricity consumption for spinning processes was 76%, and in 2023, this indicator
increased by 3%. Electricity consumption increased relatively in 2023, which in turn depends on technological processes, that is, it can be seen that this indicator has decreased in other shops.

A complete and comprehensive description of the state of electricity consumption of enterprises can be obtained as a result of studying the energy balance. It is known that the electricity balance is an assessment of how the electricity consumption of the textile industrial enterprise is distributed among the energy forms consumed by the enterprise and whether the electricity consumption is used purposefully or without purpose, and as a result of this assessment, measures for the rational use of energy resources serves as a basis for development. In addition, the role of the energy balance is extremely important in the forecasting of electricity consumption, as well as in the analysis of energy indicators. In order to analyze the enterprise's electricity consumption in detail and to determine the main points of electricity consumption for the technological process, the electricity balance for 2022 and 2023 was formed based on the data of 2 tables (Figures 3, 4) [12].

The analysis of the enterprise's electricity consumption shows that the distribution of electricity in the sections of the workshops remained almost unchanged, i.e. remained stable, during the period of 2022-2023, when the analysis was carried out. This excludes consumption for auxiliary needs.

Although electricity and gas are considered as the main forms of energy consumed in the enterprise, due to the high share of the enterprise's electricity consumption, it is necessary to determine the laws of changes in the consumption of electricity, increase the efficiency of its use in technological processes and, based on the characteristics of the technological process shows the relevance of issues of determining forecasting indicators [5, 6].

Work was carried out on the analysis of electricity consumption indicators and its forecast at the enterprise. One of the common methods of modeling and forecasting electricity consumption was the regression method [7, 8].

The general purpose of regression is to determine the relationship between several independent variables \( x_1, x_2, \ldots, x_n \) and a dependent variable \( y_1 \) in the form \( y_1 = \varphi_1(x_1, x_2, \ldots, x_n) \). In modeling and forecasting electricity consumption,
the independent variable is the production factor, and the independent variable is the electricity consumption or power load [9,10].

The instability of the initial data can lead to a high error in the forecast indicators determined using the developed forecasting model. Regression methods are very suitable for determining the important factors of electricity consumption forecasting models, but as mentioned above, they depend on the content of primary data and may not always provide high accuracy [11, 12].

3. Results and Discussions

The research of the laws of changes in the electricity consumption parameters of the spinning enterprise based on the two-year data of the enterprise, characterizing the dependence of the electricity of the product produced in the enterprise during these two years and the comparative consumption of electricity per unit of product is carried out by building energy characteristics (Figures 5-8).

![Fig. 5. Energy characteristic $W=\Pi$ of “WBM ROMITEX DIROMM” spinning enterprise (year 2022)](image)

$y = 53,086x^2 + 162,45x + 7745,6$

$R^2 = 0,6607$

![Fig. 6. Energy characteristic $e=\Pi/\lambda$ of “WBM ROMITEX DIROMM” spinning enterprise (year 2022)](image)

$y = -1,8999x^2 + 119,42x + 17,007$

$R^2 = 0,42$

The least squares method was used to construct these characteristics. In the process of product production, the laws of changes in electricity are determined in order to determine the degree of dependence of the parameters of electricity between the manufactured product.
Determining the laws of change of energy parameters will be researched based on the analysis of energy characteristics $W = (\Pi)$, $e = (\Pi)$ in the period of 2022-2023. Also, based on the initial data provided by the enterprise, energy characteristics are built.

In Figures 7-14, it can be seen that the values of the electricity consumed by the enterprise in 2022-2023 and the values of its comparative consumption indicator correspond to the values of the indicators between the products being produced. This, in turn, proves the existence of a connection between these parameters. This is based on the results of the following regression models and mathematical models (Table 3).

As a result of the statistical processing of the initial data presented by the enterprise, the dependence of the total electricity consumption and the comparative consumption indicator on the manufactured product can be seen in the following mathematical models for 2022:

$$W = 53,086\Pi^2 + 162,45\Pi + 7745,6$$  \hspace{1cm} (1)

$$e = -1,8999\Pi^2 + 119,42\Pi + 17,007$$  \hspace{1cm} (2)

where, $\Pi$ - the amount of products produced for the considered period, tons.

$W = (\Pi)$, $e = (\Pi)$ energy characteristics built for 2023, the following mathematical models were created:

$$W = -56,512x^2 + 3579,8x + 9584,4$$  \hspace{1cm} \begin{array}{c}R^2 = 0,9437\end{array}$$

$$e = -4,3619x^2 + 207,23x + 0,308$$  \hspace{1cm} \begin{array}{c}R^2 = 0,9741\end{array}$$
The value of the correlation coefficients determined by the developed mathematical models is $W = (\Pi)$ in 2022, $W=78\%$ for the energy characteristic, $e=62\%$ for the energy characteristic $e=(\Pi)$; 2023 $W = (\Pi)$, $W=96\%$ for energy characteristic, $e=97\%$ for energy characteristic $e=(\Pi)$. The high value of the correlation coefficients shows the existence of a relationship between the manufactured products and the consumption of electricity and comparative consumption indicators. This, in turn, involves the development of electricity forecasting models, taking into account the factors affecting electricity, based on the initial data provided by the enterprise when forecasting the electricity consumption and the electricity consumption indicator corresponding to the product unit. characterizes necessity and relevance.

4. Conclusions
The main goal of saving energy resources in a spinning enterprise is to improve the economic and environmental situation in the country, while increasing energy efficiency. The rational use of electricity in spinning enterprises is mainly determined by technological factors. As a result, it leads to an increase in production, improvement of product quality and reduction of the cost of goods, and at the same time, a decrease in the demand for electricity.

The analysis of the laws of changes in electricity consumption of spinning enterprises shows that there is a relationship between the products produced in the enterprise and the indicators of electricity consumption. The rational use of electricity, taking into account the factors affecting electricity, based on the initial data provided by the enterprise, is one of the main factors in improving the economic and environmental situation in the country, while increasing energy efficiency. The rational use of electricity in spinning enterprises is mainly determined by technological factors. As a result, it leads to an increase in production, improvement of product quality and reduction of the cost of goods, and at the same time, a decrease in the demand for electricity.

The high value of the correlation coefficients shows the existence of a relationship between the manufactured products and the consumption of electricity and comparative consumption indicators. This, in turn, involves the development of electricity forecasting models, taking into account the factors affecting electricity, based on the initial data provided by the enterprise when forecasting the electricity consumption and the electricity consumption indicator corresponding to the product unit. characterizes necessity and relevance.

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