

Assessment of energy saving potential in textile industry enterprises

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ABSTRACT. This article is dedicated to assessing energy-saving potential through improving the technical condition of technological equipment in textile industry enterprises without affecting production volume or quality. Considering that the energy indicators of an enterprise are directly related to the electrical load patterns of machines installed in the industrial facility, the study investigated the patterns of change in electricity consumption $P=f(A)$ and specific electricity consumption per unit of product $d=f(A)$, which are the main energy indicators of circular knitting machines. Additionally, the article presents opportunities for optimizing the specific electricity consumption per unit of output through continuous monitoring and analysis of the technological equipment's condition, as well as the ongoing organization of technical maintenance. Optimizing the specific consumption of electricity means maximizing product output and minimizing electricity consumption.

KEY WORDS: Textile Industry Enterprises, Technological Equipment, Electricity Consumption, Specific Electricity Consumption, Minimization, Production.

I.INTRODUCTION

Currently, in the textile industry, one of the main tasks is the comprehensive improvement and automation of technological processes in the development of the production of sewing and knitted products, as well as mathematical modeling of the energy performance of technological equipment. Effective organization of these tasks allows not only to increase production efficiency, but also to maximize the use of resources, save labor and time.

In the framework of the implementation of these tasks, special attention should be paid to the following important stages:

1. Technological equipment system: the integration of modern technological equipment and mechanisms significantly accelerates the production processes of sewing and knitted products, that is, by transferring the technological processes of sewing and knitted products to digital and automatic control systems, production is carried out more accurately and efficiently.
 2. Introduction of optimal operating modes of technological equipment: by determining the optimal operating modes of technological equipment for the production of sewing and knitted products, it is possible to operate the equipment at high speed and save energy. As a result, an increase in production volumes is achieved. In addition, there are no defects in the products made on this equipment, as a result, valuable knitted fabrics are not wasted.
 3. Increase reliability: The reliability of the equipment is very important to ensure the continuity of the production process of sewing and knitting products. In order to ensure the uninterrupted operation of technological equipment, it is necessary to monitor their proper operation and effectively organize current repair processes. For this, it is necessary to constantly monitor and analyze the state of technological equipment, as well as optimize technical maintenance;
 4. Improve product quality: Improving technological processes includes not only automating production processes, but also improving product quality. Perfection in technological processes significantly improves the quality of products. This, in turn, increases the competitiveness of the product.
 5. Environmental sustainability: By introducing modern technologies, great attention should be paid to environmental aspects in the production of sewing and knitting products. For example, the introduction of energy-saving technologies can reduce CO₂ emissions into the environment.
- Such changes will certainly lead to an increase in the global competitiveness of the textile industry, the production of sewing and knitting products, as well as the production of high-quality products in local and international markets. At

the same time, the installation of modern technological equipment, in turn, will allow for energy saving and rational use of energy resources, thereby increasing energy efficiency.

II. SIGNIFICANCE OF THE SYSTEM

The proposed system plays a crucial role in improving energy efficiency within textile enterprises, particularly in circular knitting machines. Since the energy indicators of a production facility are directly related to the electrical load regimes of the machines installed, the evaluation of their operational state becomes essential. The study of literature survey is presented in section III, Methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and Conclusion

III. LITERATURE SURVEY

Today, the rational use of energy resources and increasing energy efficiency are one of the most pressing problems for humanity. The depletion of non-renewable energy resources, the growing population worldwide, and the damage to the environment caused by climate change and other human factors force us to look for ways to rationally use energy resources. Many scientific studies are being conducted aimed at saving energy resources, as well as creating their reserves.

A large number of scientific and practical studies have been conducted on the rational use of energy resources and increasing the efficiency of electricity consumption at textile enterprises, which can be conditionally divided into the following 4 main groups:

- studies on the development of methodological approaches to implementing energy saving measures at textile enterprises;
- studies on the implementation of specific engineering and technical measures at textile enterprises;
- studies on improving textile production technologies;
- studies on the use of textile materials for the study of the prospects for the use of waste from textile enterprises and the creation of resource-saving technologies used in various sectors of the national economy.

Petrukhin, A.B. et al. presented the dynamics of changes in the energy intensity of Russia's gross domestic product in their research results through their scientific research. At the same time, measures aimed at improving the production process in order to increase the energy efficiency of technological equipment of textile and light industry enterprises and reduce the energy consumption of manufactured products were studied in detail.

Matveeva N.Yu. et al. proposed the structure, main stages and a detailed description of the energy audit program at an industrial enterprise. Based on their scientific research, options for reducing energy resource consumption were considered and the main measures for saving energy resources by improving energy supply and energy use systems were indicated.

Fedorov, A.S. et al. studied the main factors affecting the energy consumption of a textile enterprise. The essence of their scientific research is that social and political factors, that is, the influence of the company's employees and its management on energy consumption is significantly weaker than technological factors, but they have the greatest weight among all intra-company factors affecting energy consumption at a particular enterprise.

Kosheleva, M.K. et al. considered issues related to the creation of modern safe energy-saving technological processes for chemical finishing of textile materials. The article presents a detailed analysis of ways to increase the efficiency of heat and mass transfer processes in the finishing industry. In their study, the authors emphasize that: without improving the technology and equipment for implementing chemical technology processes for finishing textile materials, it is impossible to solve the problems of reducing energy and resource consumption in the textile industry, ensuring rational and ecological use of energy and raw materials, as well as increasing production safety.

Ozturk et al. conducted scientific research on the efficiency of energy consumption at textile enterprises. According to them, the following priority methods of energy efficiency were used: a. optimization of the technological process, b. creation of an energy monitoring and control system based on the technological process, c. optimization of steam boilers, d. modification of radio frequency (RF) dryers, e. modification of motors in the ventilation-humidification system, f. correct location of compressors, g. installation of a compressor monitoring system and modification of the air emission

cleaning system. It was found that by applying such technical measures, electricity, heat and air emissions can be reduced by 8-27%, 12-28% and 23-45%, respectively.

Khoshimov F.A. A number of proposals are made on optimizing the use of energy resources in the textile industry. At the same time, scientific research on forecasting, standardization and assessment of relative electricity consumption according to the nomenclature of products manufactured by the enterprise is presented, and mathematical models are created on their basis. Also, full energy security in industrial enterprises

Rakhmonov I. U. has carried out a lot of scientific work on the topic of minimizing the cost of electricity consumption at industrial enterprises, in particular at spinning enterprises, and has presented scientifically based solutions to the problems of managing electricity consumption at industrial enterprises of continuous production. According to the results of scientific research, he developed a control algorithm for minimizing energy costs at industrial enterprises of continuous production, taking into account the characteristics of the technological process, as well as a method for assessing energy savings reserves, taking into account the impact of raw materials on energy efficiency. In addition, he developed a mathematical expression for determining the specific electricity consumption at the enterprise, taking into account the coefficient of loss of primary raw materials in the production of finished products, as well as models for forecasting electricity consumption at the enterprise based on the main components, artificial neural networks and the criterion for minimizing their errors. The generalized standard indicators of electricity consumption were determined taking into account the auxiliary components of the enterprise's technological process.

IV. METHODOLOGY

In-depth study of the energy characteristics $P=f(A)$ and $d=f(A)$, built on the basis of the values of changes in the electricity consumption and specific consumption of technological equipment that make up the processes of knitted fabric production in the textile industry, and their comprehensive scientific analysis, create an opportunity to identify reserves of electricity savings. Such an approach serves to optimize the technical and economic indicators of the production process, ensure rational use of resources, and also increase the energy efficiency of textile industry enterprises.

At the same time, by constructing a normative energy characteristic, it allows determining the most effective range, that is, the minimum energy consumption. In the process of studying the energy indicators of the technological equipment of the textile enterprise, which is the object of the study, a number of experimental measurements were carried out to establish the energy characteristics of this equipment and it was established that the energy indicators of the technological equipment used in the production process are affected by various factors, depending on the nature of the production.

Since these factors have a deterministic and stochastic nature, the use of analytical and computational methods in assessing their energy efficiency does not give sufficient results.

Dataset Description

The above data prove that the energy indicators of the same type of equipment differ significantly as a result of technical maintenance (lubrication, repair, etc.). To increase the accuracy of calculating energy indicators, it is possible to achieve high results by conducting experiments on equipment operating at the enterprise. For this reason, measurements were carried out at the research facility, as a result of which the energy indicators of the entire enterprise were determined, the normative energy characteristics of the enterprise were compiled (Fig. 1), and the optimal ranges for electricity consumption and specific consumption in the production of knitted fabrics ($\pm\Delta W$, $\pm\Delta d$) were determined

The graph presented in Fig. 1 above shows the energy consumption of the entire enterprise in the process of knitting fabric production, as well as the specific energy consumption, $W=f(A)$ and $d=f(A)$, depending on the volume of production, and through this characteristic, the working zone of the technological equipment was determined.

Using this working zone, the optimal range of energy indicators of the entire enterprise ($\pm\Delta W$, $\pm\Delta d$), i.e., the deviation from the average value, is given in Table 1 below. Here, the symbol " $\pm$ " represents the deviation (decrease or increase) in the standard energy characteristic from the average value in the efficiency zone.

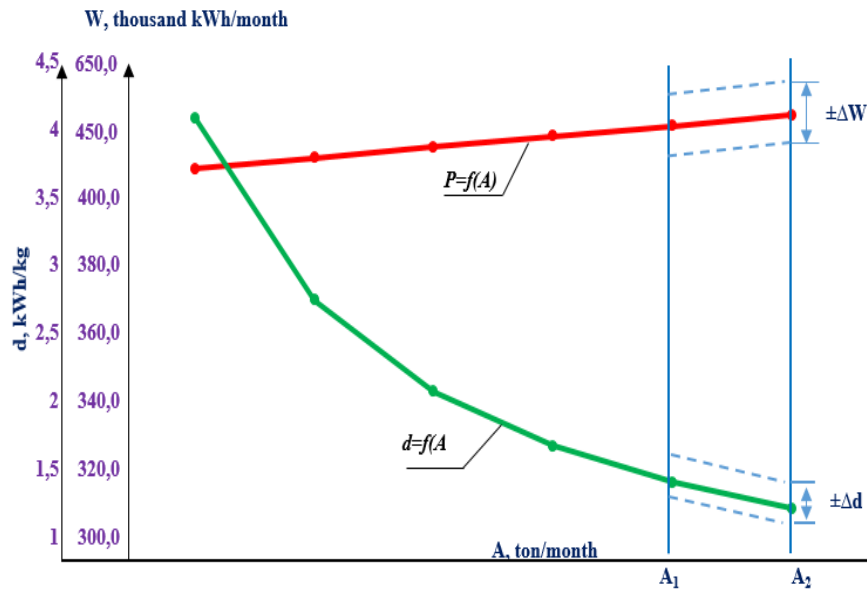


Fig 1: Standard energy characteristics of a knitted fabric manufacturing enterprise

Table 1. Deviation of the energy performance of the entire enterprise from the average value

$-\Delta W$	196071	
$+\Delta W$	477673,3	
$-\Delta d$		0,84023
$+\Delta d$		1,342668

In Table1, the optimal energy consumption of the knitted fabric manufacturing enterprise determined by the energy characteristics $W=f(A)$ and $d=f(A)$ is the normal operating mode of the enterprise, and the excess of the electrical energy consumption of the technological equipment in the working zone over the permissible limit means that the enterprise's electrical energy consumption may lead to an emergency. If it is less than the permissible limit, it allows you to assess the energy savings reserves in the enterprise.

V. EXPERIMENTAL RESULTS

Using the above energy characteristics $W=f(A)$ and $d=f(A)$ (Figure 1), the specific consumption of technological equipment in the working zone under the condition $d(A_1) \approx d(A_2)$ ($\beta = \text{const}$) is determined by the following mathematical model:

$$\Delta P = P_1(A_i) - P_2(A_i) \quad (1)$$

Here $P_2(A_i)$ is the value after applying the measures, which is determined as follow:

$$P_2(A_i) = P_1(A_i) - \sum_{i=1}^r \Delta P_i \quad (2)$$

Here r is the number of measures aimed at reducing electricity consumption; ΔP_i is the total reduced electricity consumption through the application of the i -th measure.

The reduction in the specific electricity consumption of technological equipment is determined by the following expression:

$$\Delta d = d(A_1) - \frac{P_2(A_i)}{A_i} \quad (3)$$

The total energy consumption savings of the enterprise were determined using the following mathematical expression:

$$\Delta W = \Delta d \cdot A_i (1 \pm \gamma_i) \quad (4)$$

If the components of electricity consumption and specific consumption change as a result of measures developed to save electricity (Figure 1), then the expression (2) above will be as follows:

$$P_2(A_i) = P_{average}(A_i) - \sum_1^r \Delta P_i \quad (5)$$

Here $P_{average}$ is the average electrical energy consumption of the technological equipment during the calculation period, which is determined as follows:

$$P_{average} = \frac{P_{aux.n}^c \cdot N_c (1 \pm f_i)}{T_{c.p}} + \beta \cdot A^c (1 \pm \gamma_i) \quad (6)$$

Here, $P_{aux.n}^c$ -electricity consumption in auxiliary needs of technological equipment in one cycle; N_c -number of cycles in the calculated period; f_i - resultant value of factors affecting the consumption of electric energy in auxiliary reserve; β - constant constituent of specific electric energy consumption; A^c - production volume of technological equipment during the cycle; γ_i - resultant value of factors affecting the production volume; $T_{c.p}$ - calculated period.

The following method is used to assess the energy saving reserves for the entire enterprise, assuming that the volume and quality of production do not change, and the change in electricity consumption, i.e. $d_1(A_i) > d_2(A_i)$, is the condition.

When applying measures aimed at saving electricity consumption at the enterprise, the specific consumption indicator per unit of product in the production of knitted fabrics is determined by the following mathematical model [2,5,6]:

$$d'(A_i) = d_2(A_i) - \frac{1}{A_i} \sum_1^r \Delta P_i \quad (7)$$

The relative reduction in electricity consumption as a result of the measures taken at the entire enterprise is determined by the following expression: ΔP

$$\Delta d(A_i) = d_1(A_i) - d'(A_i) \quad (8)$$

Using the expressions (7) and (8) above, the annual energy saving value of the entire enterprise is determined using the following mathematical model:

$$\Delta W = \Delta d(A_i) \cdot A_i \cdot T \quad (9)$$

Here T is the number of working days of the enterprise in a year.

Using the mathematical models presented above, a block diagram of the algorithm for estimating the energy saving reserve in the entire enterprise was developed (Fig.2).

The developed algorithm block diagram performs the following actions: as a result of conducting an energy audit of the enterprise's technological equipment on the consumption of electricity, it was found that there are no documents on the monthly and annual technical inspection of the circular knitting machine in the enterprise. It is known that regular scheduled technical inspection of technological equipment leads to a decrease in energy consumption. In this regard, a plan of measures was developed to reduce the waste of electricity of all circular knitting machines in the enterprise by drawing up timely maintenance schedules for ΔP and to constantly monitor air humidity to ensure the continuity of the production process.

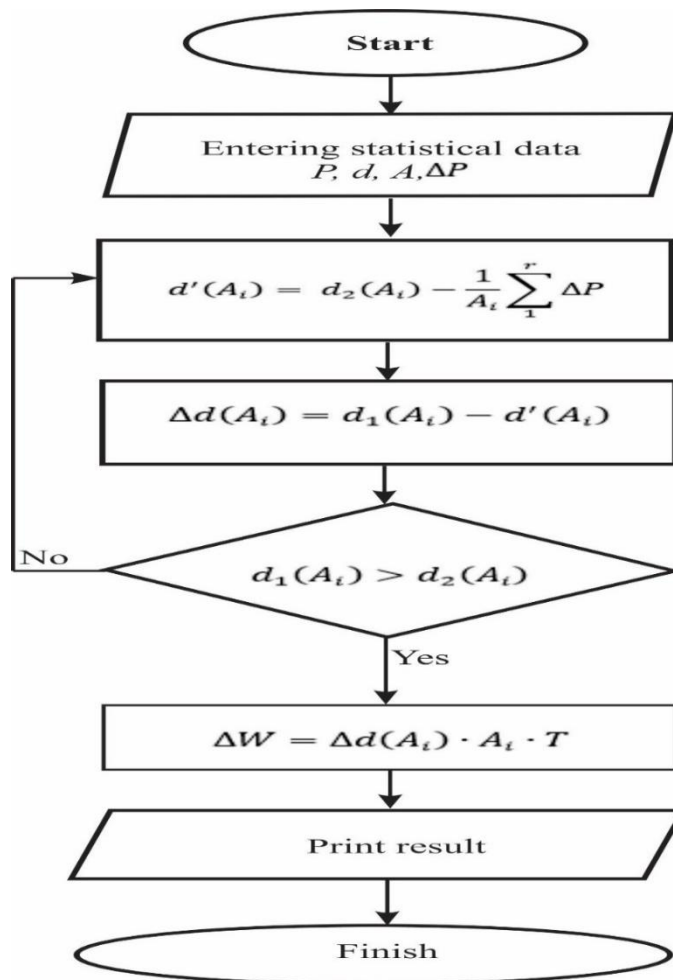


Fig. 2: Block diagram of the algorithm for estimating energy savings reserves in a complete enterprise

The total electricity consumption reduced as a result of the developed measures was calculated using the following expression: $\Delta P = \sum_1^r P_i$. As a result, the specific electricity consumption per unit of product according to the production volume of technological equipment ($\Delta d(A_2) = d(A_1) - d_2(A_2)$), $d(A_1) > d(A_2)$ decreases in accordance with the condition $d(A_1) > d(A_2)$.

If this condition $d(A_1) > d(A_2)$ is not met, that is, the specific consumption remains unchanged, then the set of measures

The annual average actual relative electricity consumption of the enterprise, kWh/kg	The annual average relative electricity consumption determined using the proposed method, kWh/kg	The difference between them kWh/kg	Annual electricity savings kWh/year
2,545	2,458	0,092	347054,1

introduced at the enterprise for energy saving should be reviewed and, if necessary, changes made. The results of this algorithm are presented in Table 2 below.

Table 2. Annual energy performance of a textile enterprise for the entire enterprise

As a result of the conducted scientific research and the application of the proposed method, the textile enterprise was able to save 3.2% of its annual electricity consumption.

VI. CONCLUSION AND FUTURE WORK

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

The analysis of the laws of change in electricity consumption at textile enterprises shows that there is a relationship between the products produced at the enterprise and the indicators of electricity consumption, and by studying this relationship, opportunities for increasing energy efficiency are achieved. In addition, it was scientifically substantiated that efficiency can be achieved by applying energy-saving measures in electrical equipment installed at the enterprise.

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