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ANALYSIS AND MATHEMATICAL MODELING OF ENERGY CONSUMPTION OF LINTERING MACHINES IN COTTON GRINDING ENTERPRISES

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Abstract. *Estimation of energy consumption in the processing of cotton raw materials in a linter, determination of the laws of change of electrical loads and relative energy consumption and the most convenient modes. Also, it is important to correctly determine the installed power of electric drives of linter machines and determine the required power on the shaft of their engines, and to analyze the energy performance of the enterprise and workshops.*

Keywords. *linter of cotton ginning enterprises, the intensity of the supply of cotton to the linter, the total installed capacity of linters, the efficiency of the linter, the relative energy consumption of the linter.*

Annotatsiya. *Paxta xomashyosini linterda qayta ishlashda energiya sarfini baholash, elektr yuklamalarining o'zgarish qonuniyatlari va nisbiy energiya sarfi hamda eng qulay rejimlarni aniqlash. Shuningdek, linter mashinalari elektr yuritmalarining o'rnatilgan quvvatini to'g'ri aniqlash va ularning dvigatellari validagi zarur quvvatni belgilash, hamda korxona va sexlarning energetik ko'rsatkichlarini tahlil qilish muhim ahamiyatga ega.*

Kalit so'zlar. *Paxta tozalash korxonalari linteri, linterga paxta berish intensivligi, linterlarning umumiy o'rnatilgan quvvati, linterning foydali ish koeffitsienti, linterning nisbiy energiya sarfi.*

Аннотация. *Оценка энергопотребления при переработке хлопкового сырья в линтере, определение закономерностей изменения электрических нагрузок и относительного энергопотребления, а также наиболее удобных режимов. Также важно правильно определить установленную мощность электроприводов линтерных машин и определить требуемую мощность на валу их двигателей, а также проанализировать энергетические показатели предприятия и цехов.*

Ключевые слова. *линтер хлопкоочистительных предприятий, интенсивность подачи хлопка в линтер, общая установленная мощность линтеров, коэффициент полезного действия линтера, относительное энергопотребление линтера.*

INTRODUCTION

In the world, scientific and research work is being carried out aimed at developing new scientific and technical solutions for improving cotton processing and product quality, optimizing technological equipment and operating modes using energy-efficient technologies. In this regard, taking into account the fact that cotton processing is mainly seasonal, special attention is paid to increasing the operational efficiency of electrical equipment used in the implementation of processes and thereby achieving energy efficiency in the industry.

The purpose of the study is to develop scientific foundations for increasing the energy efficiency of technological devices at the stage of processing cotton raw materials, taking into account the characteristics of cotton varieties, taking into account the characteristics of cotton varieties, while preserving the natural qualities of fibers and seeds.

MATERIALS AND METHODS

To analyze the main technologies for estimating energy consumption in the processing of cotton raw materials, probability theory and mathematical statistics, mathematical analysis, the principal components method, and correlation-regression methods were used.

RESULTS AND DISCUSSION

Cotton seed linting processes Cotton seed linting processes are carried out at cotton ginning plants. The linting process is carried out in order to separate this lint from the seed composition. Linting of cotton in cotton ginning plants is carried out in saw linters, which undergo various levels of intensive processing.

Depending on the need to obtain one or another type of lint, the following linting technologies can be used - the first two-stage enhanced lint removal, the second two-stage enhanced lint removal and the third stage lint removal. These processes are carried out by the PMP-160M linter machine with the UPML working chamber, 5LP and 6LP linters and units with the help of saw teeth and strong air separation.

In saw linters, the linting process is based on the mechanical action of rotating roller saws with the grain, as a result of which the teeth scrape off the fiber (lint) from the surface of the grain removed from the saw, which is sent to the condenser by air.

The main indicators of linter performance are: the amount of lint removed from the grain and the degree of lint exit from the grain, and the linter efficiency is calculated. Depending on the selected linting technology and the need to produce the required type of lint, taking into account the control of the linter operation, the appropriate lint removal for each type of lint is studied experimentally by adjusting the linter efficiency.

A comprehensive study of the linting process requires the disclosure of a number of factors, the main indicators of which are the productivity, the degree of lint removal and its quality:

seed selection, industrial grade and fineness of the fiber in the seed (the amount of fluff); linting mode; the condition of the saws and their diameter; the parameters of the linter working chamber and its working bodies, and the speed modes of the mixer and saw cylinder.

The effect of cotton selection and industrial grades on the productivity of linting machines and linting quality is determined, in particular, by a significant difference in the linting indicators of the seed after ginning.

Depending on the need to obtain a particular assortment of lint, the appropriate linting technology is selected. To obtain a full range of lint, it is necessary to undergo a three-stage linting technology, first by removing 2%, secondly by removing up to 4%, and thirdly by removing 2% or more. Double linting ensures maximum output of the second type of lint by removing the first reinforced lint (up to 6%), and the second linting (with 2% removal) produces the third type of lint.

During the first linting process, lint removal exceeding 6% leads to a significant unevenness of the produced lint along the length, which is related to the third type, as well as to an increase in its clogging. The technology of double linting with an increased secondary removal leads to an increase in the first type 1 lint (removal up to 2%) and an increase in the second type 3 lint with a lint removal of 6% or more [20; pp. 52-67].

During the first linting, the condition of the working chamber of the machine and the mixer in it significantly affects the work efficiency. The condition of the chamber and the mixer in it, the gap between the mixer grates and the saws, the protrusion of the saws and the pitch of the saw teeth have the most important effects on lint removal.

Experimental studies of the first and second linting processes have shown that it is necessary to calculate the equations related to the work efficiency (while maintaining a certain lint removal) taking into account the 3 most important factors - the position of the working chamber relative to the saw cylinder, the speed of the mixer and the saw:

1st linting (2% lint removal):

$$A_1 = 1121 + 1{,}2n_{пц} + 15{,}7\alpha - 0{,}1n_{пц}\alpha + 0{,}2n_B\alpha, \text{ kg/h} \qquad (1)$$

2nd linter (4% lint removed)

$$A_2 = 2431 - 1{,}5n_{пц} - 4{,}4n_B + 65{,}7\alpha + 0{,}006n_{пц}n_B - 0{,}006n_{пц} \quad \text{kg/h} \qquad (2)$$

where - A_1, A_2 the efficiency of the saw linter in the first and second linting of seeds, kg/h;

$n_{пц}, n_B$ - rotation speed of the saw cylinder and mixer, rpm;

α - the angle of rotation of the working chamber relative to the cylinder (5 LP from the main position in the linter), grad.

The values of the following factors in the experimental field $n_{пц} = 630$, $n_ц = 830{,}400$, $n_B = 600$ the adequacy of the equations for; $\alpha = 10°$.

While maintaining the state of the working chamber, as in the 5LP linter, the equations are simplified and take the following form:

1st linter (linting removal - 2%):

$$A_1 = -301 + 1{,}2n_{пц} + 3{,}2n_B \text{ kg/h} \qquad (3)$$

2-Lintering (Linter removal - 4%):

$$A_2 = 2431 - 1{,}5n_{пц} - 4{,}4n_B + 0{,}006n_{пц}n_B \text{ kg/h} \qquad (4)$$

Based on the data provided and the calculations obtained from the equations, it is possible to select linter technology and its modes in order to increase the efficiency of lint production at cotton ginning enterprises.

Saw linter machines PMP-160M can replace low-performance linters with 5LP linter machines and ensure the production of products with high quality indicators. The main difference between the 5LP linter and the PMP-160 linter is the enlarged working grain chamber. Adjusting the linting process with a grain comb changes the lint output from the grain and the machine's productivity. With an increase in the distance between the grain comb and the grid, the removal of hairs from the grain decreases and at the same time the grain throughput increases.

After setting a certain gap between the grain comb and the grid, it is possible to increase the productivity of the linter by using an automatic control system, taking into account the optimal density of the grain in the working chamber along a certain length of the lint production.

The pulse variator is designed to automatically control the supply of grain to the working chamber of the linter by changing the rotation speed of the supply drum depending on the change in the density of the grain in the grain roller. The intensity of the supply of grain to the linter, its productivity, is established experimentally, taking into account the required density of the grain roller.

The change in the position of the load on the handle of the valve density and its weight affects the density of the grain roller and the productivity of the linter. The constant load of the linter machine itself increases the productivity of the grain linter and vice versa. Increasing the density at the valve stem is usually used when a small change in the linter's grain supply is required.

Depending on the design of the linters, saws with a diameter of 320, 310, 300 and 290 mm are used. To facilitate the process of installing new or roller saws on the linters, it is recommended to try using one or another linter with a constant diameter. When installing saws of other diameters on the linter, the position of the air chamber and the grate is adjusted.

The output of the saws above the grate is carried out by adjusting the support bolts of the shaft under the grate and the suspension mechanism of the linter's working chamber. The separation of sawdust and foreign impurities from the lint is regulated by means of a sawdust cover that can be moved towards or away from the saw. Since the sawdust is processed in three linting operations in sawdust linters after collection, we experimentally determined the energy consumption of each lint output and the actual average work efficiency.

Mathematical models of energy consumption characteristics of PMP-160, PMP-160m and 5LP saw linters are expressed as follows:

For PMP-160 and 160M: for first output

$P'_{ПМП} = 25{,}3 + 0{,}0018\,A'_{ПМП}$ kWt; (5)

$d'_{ПМП} = \dfrac{25{,}3}{A'_{5ЛП}} + 0{,}0018$ kWt·h/kg. (6)

for the second exit

$P''_{ПМП} = 25{,}3 + 0{,}0021\,A''_{ПМП}$ kWt; (7)

$d''_{ПМП} = \dfrac{25{,}3}{A''_{ПМП}} + 0{,}0021$ kWt·h/kg (8) for the third exit

$P'''_{ПМП} = 25{,}3 + 0{,}0028\, A'''_{ПМП}$, kWt; (9)

$d'''_{ПМП} = \frac{25{,}3}{A'''_{5ЛП}} + 0{,}0028$ kWt·h/kg (10)

For 5 LP brand saw linters: for first release

$P'_{5ЛП} = 24{,}8 + 0{,}0016\, A'_{5ЛП}$ kWt; (11)

$d'_{5ЛП} = \frac{24{,}8}{A'_{5ЛП}} + 0{,}0016$ kWt·h/kg. (12)

for the second exit

$P''_{5ЛП} = 24{,}8 + 0{,}0022\, A''_{5ЛП}$ kWt; (13)

$d''_{5ЛП} = \frac{24{,}8}{A''_{5ЛП}} + 0{,}0022$ kWt·h/kg. (14)

for the third exit

$P'''_{5ЛП} = 24{,}8 + 0{,}0027\, A'''_{5ЛП}$ kWt; (15)

$d'''_{5ЛП} = \frac{24{,}8}{A'''_{5ЛП}} + 0{,}0027$ kWt·h/kg. (16)

The useful composition and load losses of saw linters during nominal operation do not exceed 5-8% of the energy consumption.

From expressions (15) and (16) it can be seen that the average energy consumption of saw linters does not depend on the productivity, and this characteristic can be considered universal and describes the laws of changing the power consumption and relative energy consumption for fibers of different lengths produced by a saw linter.

The 6 LP linter machine is produced in 2 types according to its operating function: 6 LP and LP-1 are designed to perform two-time final linting of the grain in one machine, and the linting process is carried out in the same way as in saw linters of the PMP-160M and 5 LP brands. The 6 LP linter machine has two section saw cylinders, each with 160 saws.

6 The LP-01 linter machine also has two section saw cylinders, each with 100 and 160 saws, which provide 6% yield of first and second type lints. One of the main indicators of the machine is the high output level of lint from the upper and lower linting sections, that is, high productivity.

During linting, the feeder is adjusted in the lower section of the working chamber of the machine depending on the volume of grain on the roller. To increase the efficiency of the machine, the density valve in the lower linting section of the working chamber is adjusted by changing the lever connecting the variator with the density valve, as well as moving the load to the handle of the density valve.

The operating mode lasts a long time with a constant load. The total installed capacity and the efficiency of the 5LP PMP-160M UMPL chamber saw linters in terms of grain can be seen in Table 1.

Table 1

Mathematical models of the energy consumption characteristics of the PMP-160, PMP-160m and 5LP saw linters

№	sawn brand of linters	Installed capacity, kWt	Seed productivity, kg/h	Comparative energy consumption, kWt·h/kg
1.	PMP-160 PMP-160M	31,2	In the first release of fiber 2000	$d'_{ПМП} = 0{,}0156$
			in his second appearance 1700	$d''_{ПМП} = 0{,}0184$
			on his third appearance 1300	$d'''_{ПМП} = 0{,}024$
2.	5LP	30,6	In the first release of fiber 2300	$d'_{5LP} = 0{,}0133$
			in his second appearance 1700	$d''_{5ЛП} = 0{,}018$
			on his third appearance 1360	$d'''_{5ЛП} = 0{,}0225$

In each of the linting sections, the necessary lint is removed using lint combs, similar to the 5LP brand of sawn linters. The removal of hairs and impurities from the lint is carried out by adjusting the air chamber covers of the upper section.

Synchronization of the operation of the upper and lower linting sections in the set modes, as well as ensuring their stable operation, is carried out by moving the lever columns connecting the density valve of the lower section with the variator.

When starting the linter at high load, the upper column of the upper section should be lowered. To accelerate the filling of the upper section with lint, the column of the lower section should be raised. The installed power of the 6LP brand linter machine is 61.2 kWt. The linter's working efficiency is 88 kg/h for lint and 1180 kg/h for lint. The planned value of the relative energy consumption of the linter is 695 kWt·h/t for lint and 52 kWt·h/t for sawdust.

Formulas have been developed to calculate the power consumption and relative energy consumption depending on the performance of the linter.

$$P_{6ЛП} = 44 + 0{,}009\,A_{6ЛП}\,, \quad \text{kWt} \qquad (17)$$

$$d_{6ЛП} = \frac{44}{A_{6ЛП}} + 0{,}009\,, \quad \text{kWt·h/kg} \qquad (18)$$

In accordance with expressions (17) and (18), the normative energy characteristics of the power consumption and relative energy consumption of the 6LP linter machine are constructed.

The study of the electrical load modes of the main machines and mechanisms of the cotton ginning industry showed that:

- assessment of the energy consumption of all varieties of cotton raw materials processed in each cotton ginning and linting machine according to their design features and production technology;

- determination of the laws of change and the most favorable modes of electrical loads and relative energy consumption for saw and roller gins, as well as linters. Determines the directions for reducing inefficient energy costs by reducing the maximum electrical loads at the enterprise, reducing the costs of traditional commissioning;

- development of a reliable empirical formula that allows to correctly determine the installed power of electric drives of jin-linter machines and to determine the necessary power falling on the shaft of the engine;

- the need to create a base for analyzing and predicting the energy indicators of the enterprise and shops as a whole was justified.

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