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FUNDAMENTALS OF SELECTION PROCESS OF THE EQUIPMENT FOR FOOD PRODUCTION PACKAGING LINES

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ABSTRACT

The priority tasks of scientific and technical nature, the solution of which creates the conditions for improving the operation of packing equipment, include the introduction of modern hardware, software, methods and algorithms for parametric control and diagnostics of the equipment, as well as the implementation of tools and methods for the control of technological parameters in real time operation. OEE criterion (Overall Equipment Effectiveness) allows detecting losses and reasons for inefficiency. As a result, both breakdown stoppages and losses due to inefficient operation of the equipment, slow performance or pending delivery are identified. Therefore, OEE enables to evaluate the effect of current performance of a particular piece of equipment on the efficiency of the whole production. The resulting values of the parameters of operation reliability are compared with the corresponding values of previous periods. This approach provides means for assessing the equipment reliability.

ОСНОВИ ВИБОРУ ТЕХНОЛОГІЧНОГО ОБЛАДНАННЯ В ПАКУВАЛЬНИХ ЛІНІЯХ ХАРЧОВИХ ВИРОБНИЦТВ

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До пріоритетних завдань науково-технічного характеру, вирішення яких створює умови удосконалення процесу експлуатації пакувального обладнання, відносяться: впровадження сучасних апаратних засобів, методів і програмно-алгоритмічного забезпечення параметричного контролю й діагностування обладнання, впровадження засобів і методів контролю технологічних параметрів в умовах реального часу. Критерій OEE (Overall Equipment Effectiveness) дає змогу виявити втрати і причини неефективності роботи. В результаті виявляються не тільки простої через поломки, але й втрати через неефективну роботу обладнання, зниження продуктивності або очікування надходження матеріалів. У кінцевому підсумку OEE надає можливість простежити, як впливають значення поточної продуктивності окремої одиниці обладнання на ефективність роботи цілого виробництва. Отримані в результаті обробки значення параметрів надійності в процесі експлуатації *порівнюються з відповідними значеннями показників за попередні періоди. Такий підхід дає змогу проводити оцінку якості рівня надійності обладнання.*

Ключові слова: *критерій діагностування, синтез, пакувальне обладнання, OEE (загальна ефективність обладнання).*

Introduction. Among the important tasks of enhancing the operation of packing equipment is improving the system of collection, processing and analysis of information about the technical condition and reliability of technical systems.

Timely detection of points of origin of degradation processes that determine the timing of the transition in the limit state made for every type of functional modules of the technological line is to control the level of reliability engineering on the stage of its layout and operation.

Problem Statement. A common disadvantage of software simulations is that they are given for the use of common methods of single and multicriteria optimization, each having its own limitation on the use, accuracy and speed of getting results. This prevents a comprehensive, unified position, to assess the quality of the future equipment in various stages of design and at the same time optimize its structure and settings. The structure of the play is the technological line (PTL), which can be presented on the basis of two phases of assessment: structural and parametric synthesis (Figure 1). The concept of "optimal solution" is the best in the given sense of the solution of the problem that allowed conditions. And nothing is more complex, as to prove that this solution is really optimal. Especially difficult it is to talk about optimality of PTL packaging of food products. Mostly the same technical problem can be solved in multiple ways, which differ not only in external features, diagrams and designs, but also in physical principles, bricked in its base. Therefore, a "competitive alternatives" of PTL packing foodstuff or its individual parts are developed. As a result, each of the choices of food packaging PTL has its advantages and disadvantages. There is a new kind of problem: which of the available alternatives to choose for further improvement. Process for the synthesis of PTL packing food is mainly divided into three main stages: structural (functional) synthesis, associated with the definition of the principles of system functioning, developing its structural diagrams (list elements and methods of communication between them) in accordance with the requirements of the technical specifications (TS); parametric (design) synthesis, which covers the question of choice of spatial layout design, definition of numeric values of design parameters within the chosen structure, taking into account the conditions of capacity and requirements to source parameters; technology synthesis, associated with the solution problems of the construction of technological processes of the final product manufacturing.

In order to assess the reliability of the play the technological systems of packaging lines used by established standards of performance are given in Table 1. From Table 1 we see that their reliability (for example, maintainability) characterizes only one of the properties of a technical object line, while comprehensive indicators characterize several properties, and in the future they will be used as a key to assess the effectiveness of such complex objects like line and its functional modules. These indicators include the coefficient of operational readiness and maintenance and the coefficient of preserving the efficiency [1]. Coefficient of readiness $K_Г(t)$ is taken to determine how probable is that the object will be in working condition at any point in time, in addition to the scheduled periods, during which the application object for other purposes is not envisaged [2].

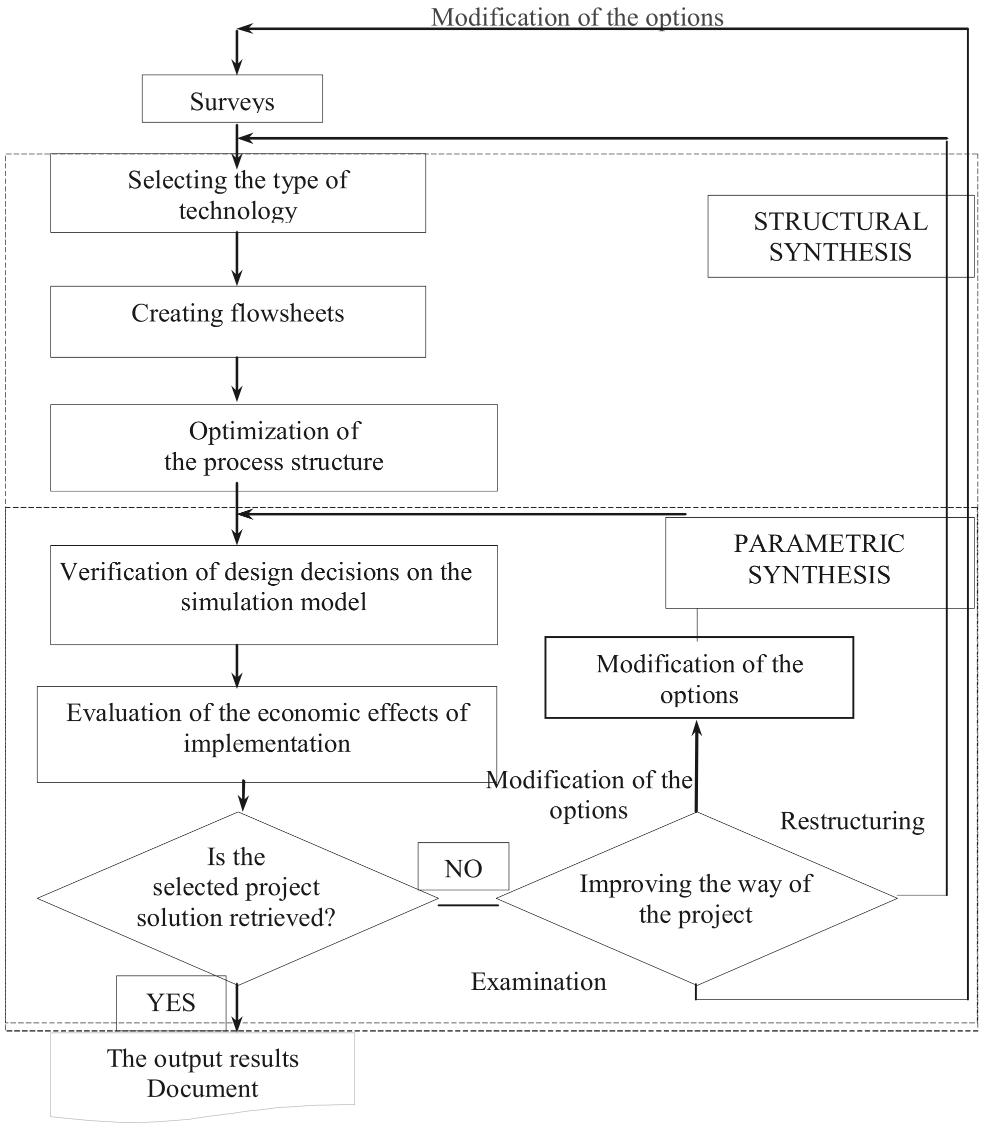

Fig. 1. Block diagram of the process of computer-aided design

Reliance $K_Г(t)$ from time to time is often referred to as the transient coefficient of readiness (the function of readiness). An expression for the unsteady coefficient of readiness in the analytic form is quite difficult to be obtained and generally it has the form [2]:

Table 1. **The main indicators of reliability**

Property	Indicator 2	Marking 3
The main indicators of reliability		
Infallibility	Reliabilities	$P(t)$
	Failure	$\lambda(t)$
	Failure flow parameter	$z(t)$
	Mean time to failure	T_1
	Mean time between failures	T_0
Durability	Average yield	T_n
	Operating resource (average lifetime)	T_e
	Gamma-percent life time	$T_{\gamma e\%}$
Maintainability	The probability of recovery	$P_в$
	The probability of recovery	$\mu(t)$
	Intensity recovery	T_B
	The average duration of recovery	T_3
Preservation	Medium term safety	$T_{\gamma 3\%}$
Preservation	Gamma-term interest safety	
Complex		
Faultlessness and maintainability	The availability index	$K_Г$
	Coefficient of operational readiness	$K_{0Г}$
	Coefficient of technical use	K_{TB}

$$K_Г(t) = P(t) + \int_0^t P(t-\tau)\omega_в(\tau)dt, \tag{1}$$

where $\omega_в(\tau)$ is an option of stream restorations.

Along with this, for any distribution of an operating time between failures and recovery time can prove that a stationary coefficient of readiness is:

$$K_Г = \frac{M(T_0)}{M(T_0)+M(T_B)}, \tag{2}$$

where $M(T_0)$ — expectation of time finding PTL in employers capable state; $M(T_B)$ — expectation of PTL cooldown. Along with $K_Г(t)$ injected coefficient of operational $K_Г(t)$, t is probable that the object will be in working condition in a random amount of time, in addition to the scheduled periods, during which the application object for other purposes is not envisaged, and from this point it will work flawlessly during the set time interval

$$K_Г(t, t+\tau) = P(t+\tau) + \int_0^t P(t+\tau-x)\omega_в(x)dt, \tag{3}$$

For the study of the impact of implemented methods and modes of maintenance and repair of the efficiency of the process of technical operation is used another comprehensive reliability — the coefficient of the technical use K_{TB}, which is equal to the relation of mathematical expectations (ME) time of an entity in working condition for a period of operation $M(T_0)$ to sum ME time entity is in working condition and the total time of downtime on all types of maintenance and repair work:

$$K_{TB} = \frac{M\left(T_0\right)}{M\left(T_0\right) + M\left(T_{np}\right)}, \tag{4}$$

where $M\left(T_{np}\right)$ is the amount of mathematical expectations of downtime on the periodical, routine, seasonal work, during work, repairs, troubleshooting, etc. In practice, in the course of operation of the packaging lines for assessment of reliability are used, as a rule, indicators of the intensity of the bounce, the stream of rejections, the average operating time of average denial of a waiver.

In the technical literature [3—5] the approach for evaluating the reliability of technical articles (the intensity of the bounce, the stream of rejections) is generally considered as a function of the operating time with the different laws of the distribution of time between failures. Methods of statistical evaluation of indicators for different test plans (observations) for reliability are embodied in State standards of Ukraine. But, as noted, the real conditions of operation of the equipment do not match any plan established by the standard. Some authors indicate that the physical wear of functional modules of technological lines occurs both during their usage for other purposes (the wear of the 1st kind) and during downtime store (the wear of the 2nd kind) [3,4].The analysis of the literature shows the lack of clearly justified recommendations for taking account of the impact on the value of statistical estimation of reliability index of the functional module in the packaging line and taking into account the end of technological indicators. For evaluating the level of the reliability of the renewable entities the characteristics of the stream flow bounce is used: bounce $\hat{z}$ or the operating time to refusal $\hat{T}_0$:

$$\hat{z} = \frac{n}{t_\Sigma}, \quad \hat{T}_0 = \frac{t_\Sigma}{n}, \tag{5}$$

where n — is the total number of failures and damages that were detected by the test period of operation τ aggregate of products; t_Σ — is the total operating time of the totality of the similar products in the same period of time τ.

It was assumed that the product affects the two independent streams of bounce. The first stream of failures is associated with operating time, the second – with calendar time of its operation. Both streams are easier with the relevant intensities z_1 and z_2. This product is an object with variable mode of operation. Taking into account the following assumptions in some literature one can find the following limit value [2] from whence we get:

$$z_1 + \frac{z_2}{K_I} = z = \frac{1}{T_0}, \tag{6}$$

$$\frac{K_I}{z_1 K_I + z_2} = T_0, \tag{7}$$

$$K_I = \frac{T_e - T_{TO} - T_{rec} - T_{s\tan d}}{T_e} \approx \frac{t}{T_e}. \quad (8)$$

where: T_e — the calendar of product operation for the period (year, half year); T_{TO} — average time, then the product during the same period; T_{rec} — average time of recovery of the product during the period; T_{stand} — average idle time of products during the period without use, hours; t — the average operating time of the product during the period.

For its content K_I is similar to the rate of the planned application of the $K_{ПЗ}$, but the last account operating time that is planned, and ignores the idle time without applying for the purpose. Using the expression (8) you can perform quality and quantify the impact of the intensity of the exploitation of the product K_I to rate its reliability (reliability) T_0. High quality (8) shows that with increasing intensity of operation of the totality of the products K_I increases the numerator and the denominator the product of $(z \cdot K_I)$, but in the relationship so that the $z_1 < 1$, the numerator is growing faster, so the assessment T_0 also increases:

$$K_I \uparrow \Rightarrow \frac{K_I \uparrow\uparrow}{(z_1 K_I)\uparrow + z_2} \Rightarrow T_0 \uparrow. \quad (9)$$

On the contrary, with a decrease in the intensity of the exploitation of the totality of the products $K_I \downarrow$ evaluation average operating time to failure and damage to the T_0 is decreasing too.

$$K_I \downarrow \Rightarrow \frac{K_I \downarrow\downarrow}{(z_1 K_I)\downarrow + z_2} \Rightarrow T_0 \downarrow. \quad (10)$$

Thus, statistical reliability varies depending on the intensity of the operation, although the actual level of credibility in this case remains the same.

Consider the extreme cases. Obviously, with enough high intensity happening quick exhaustion of resource products for operating time, there are no lengthy downtime without the use for other purposes, so the intensity of flow failures, aging-related materials $z_2 \rightarrow 0$. In this case:

$$T_0 = \frac{1}{z_1}, \quad (11)$$

that between periodic score allows enough to accurately assess the real level of reliability and does not depend on changes in the intensity of use. In this case there have been long-term downtime without the use for other purposes is an intensive ageing materials design on stage, when achieved by completion of resource calendar terms of service when a significant balance of resource operating time. In the limiting case when the observed high values of z_2 at $z_1 \rightarrow 0$, the expression (8) view:

$$T_0 = \frac{K_I}{z_2}, \quad (12)$$

that indicates a directly proportional dependency evaluation indicator (7) depends on the intensity of use.

Consider the approach which criterion of OEE (Overall Equipment Effectiveness) is best suited for packing equipment-approach to the surveillance and management of material, information flows. It was introduced in the late sixties of the last century Japanese Nakajima (Seiichi Nakajima), but started to be used outside of Japan only in the late eighties. The essence of the approach is an analysis of the traits that characterize different aspects of equipment, which include simple, reducing speed and loss of quality. The structure contained method of analysis which is consistent immersion into the problem area, whether it be a not optimal organization of work equipment, low performance or lack of products. As a result of the analysis turns out to be the cause of reduced effectiveness, on which it is necessary to focus attention. The criterion of OEE allows you to detect loss and causes of the inefficiency of the work. As a result are not only simple because of the damage, but the loss due to ineffective work equipment, decreased performance or expectation of receipt of materials. Eventually OEE allows you to trace how the influence of the current performance of the individual piece of equipment on the efficiency of the entire production.

The availability of reliable measurement results the performance of funds allows you to make informed decisions about investments that provide a rapid return on investment. Based on OEE concludes, is it possible to improve productivity on existing equipment or its capacity is almost exhausted and to increase productivity, it is necessary to install new functional modules or new equipment. For the analysis of the effectiveness of the equipment developed system of KPI (Key Performance Indicators key performance indicators). But before you start them consider necessary to agree on terminology. As already mentioned, the OEE is an approach to monitoring the work of the equipment. At the same time very often under the OEE is understood as its own coefficient, which characterizes the work of the equipment. To avoid confusion in the future will talk OEE, when talking about the approach, and the “criterion of the OEE” in the second case. In fact, the criterion of the OEE is the ratio of fully productive time (perfect time) before the scheduled time of the work. Taking into account the loss of productivity and quality of this coefficient can be calculated by the formula 1.

$$\text{Availability Rate} = \frac{\text{Operating Time}}{\text{Total Available Time} - \text{Scheduled Downtime}},$$

$$\text{Performance Rate} = \frac{(\text{Total Production} \ / \ \text{Production Time})}{\text{Ideal Run Rate}},$$

$$\text{Rate the quality} = \frac{(\text{Total Production} - \text{Total Scrap})}{\text{Total Production}}.$$

Easy to see that substituting the values of the factors in the formula 1 and taking shortcuts, you can get that figure equals the OEE regards the amount of high-quality products to the planned time times the perfect speed. Thus, it can also be defined as the ratio of the volume of high-quality products to the ideal amount that could be made if the equipment work during scheduled time at maximum (ideal) [6].

Table 2.

	Machine	Scrap 1	Scrap 2	Total Production	Total Available Time	Scheduled Downtime	Unscheduled Downtime	Operating Time	Ideal Run Rate	Availability Rate, %	Performance Rate, %	Rate the quality, %;	OEE, %
1	Pastpack P	1	3	2000	2000	20	78	1902	1.25	96.1	84.1	99.8	80.6
2	"Pastpack P Servo"	2	5	2400	3000	20	80	2900	1.1	97.3	75.2	99.7	73.0
3	Pastpack P2	3	4	1800	3500	20	78	3402	1	97.8	52.9	99.6	51.5
4	"Pastpack P2 Servo"	4	2	2100	3700	20	80	3600	1.1	97.8	53.0	99.7	51.7
5	Pastpack P2 (2)	5	3	3600	3800	20	78	3702	1	97.9	97.2	99.8	95.0

a) b) c) d) e)

Fig. 2. **Packaging machine that to realize these package type:** a) Pastpack P; b) "Pastpack P Servo"; c) Pastpack P2; d) "Pastpack P2 Servo"; e) Pastpack P2 (2)

The fact that the observation of the value of the OEE is a kind of starting point. Discover the OAE is different from the target (for example, it fell in comparison with the previous period), you can see what impact this fall. Analyzing the value of each of the three factors and comparing them, for example, the values for previous periods, we gradually localize the cause of the loss of efficiency. If the problem lies in quality or reduce the speed of the equipment, then this is a signal for the relevant services. If the problem lies in the area of accessibility, it is possible to make a more in-depth analysis of the reasons that we consider a bit later, when we talk of control equipment. According to research [1] best world manufacturers reach the level of the production process with the OEE is above 85%. The value of basic indicators in the case of the achievement of the value given in table 1. These data are vital for continuous production. For discrete industries similar to OEE metric is equal to 80% [2].

The results are shown in figure in spreadsheet format, developed by its own algorithm.The results of the offer the opportunity to track the effectiveness of a particular machine in a line or functional module by OEE. And upgrades, or replacement of the most challenging management PTAS for improvement of equipment.

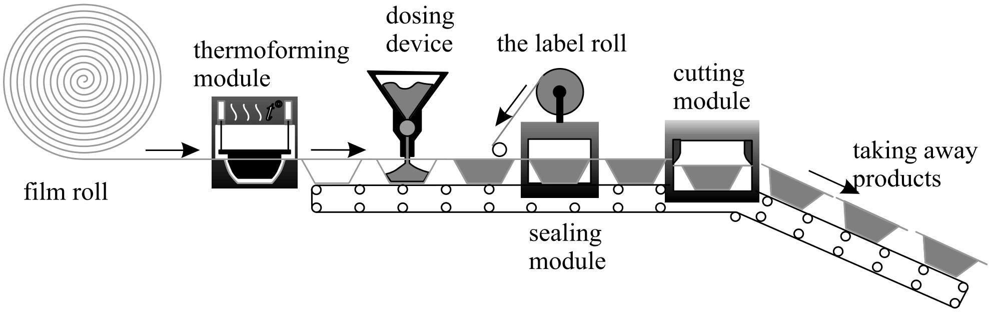

Fig. 3. Diagram of the process line of packaging on the basis of functional modules

Note that for many companies the value of quality score exceeds the specified in table 1. However, in accordance with the mentioned research the average indicator of OEE for producers not to exceed 60%. This fact points to a potential optimization of production in the field of performance and availability. We developed a spreadsheet instructions OEE calculator spreadsheet, which simplifies the task to calculate individual and combined figures of OEE to study PTS to ten machines. The example given below on Fig. 4, obtained by an open information for equipment: automatic thermo — forming a weighing-and-packing line TAURUS-full cycle of wrapping and packaging of any products, starting with the blowing of plastic container or beaker polymer film, filling out their product (commodity) using the dispenser, coversealing material with printed label and the cutting sealed cups or containers filled with product (commodity) into separate containers.

Table 3. **Specification filling and packaging machines series "Pastpack P" and "L Pastpack"**

	Pastpack P	"Pastpack P Servo"	Pastpack P2	"Pastpack P2 Servo"	Pastpack P2 (2)
1	2	3	4	5	6
Specifications					
Performance (Pkg. / Min.), max. *	33	40	30	35	60
Performance (Pkg. / H) max *	2000	2400	1800	2100	3600
The diameter of the round container (mm) max	101	130	130	190	95
The dimensions of the rectangular container (mm) max.	126x90	142x92	192x42	192x42	95x78
Height of container (mm) max.	120 (200)	120 (200)	120 (200)	120 (200)	120 (200)
The drive of the transport system	Electro-mechanics	Servo	Electro-mechanics	Servo	Electro-mechanics
connection	220 V, 1 phase, 50 Hz	220 V, 1 phase, 50 Hz	220 V, 1 phase, 50 Hz	220 V, 1 phase, 50 Hz	220 V, 1 phase, 50 Hz
Installed power, kW	2,2	3,5	2,2	3,5	2,2
The pressure in the pneumatic system, MPa	0,6	0,6	0,6	0,6	0,6

Continuation of table 3.

1	2	3	4	5	6
Compressed air consumption, Nl / min	350	450	350	450	500
*Machine dimensions, not more than					
Length (mm)	910	1025	1600	1600	1600
Width (mm)	880	940	1480	1480	1480
Height (mm)	1980	1980	1980	1980	1980
Weight, (kg)	400	400	650	700	500

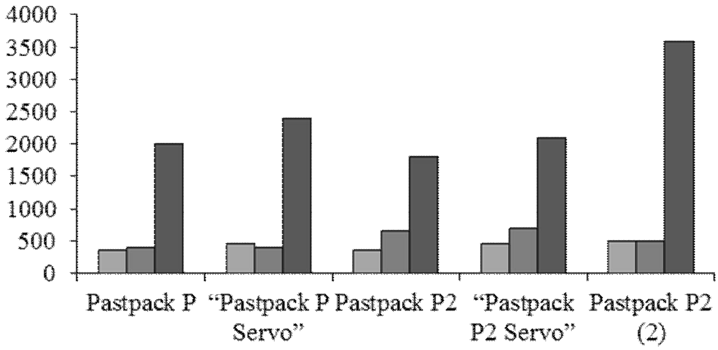

Fig. 4. Diagram specification filling and packaging machines series "Pastpack P"

Conclusions

Obtained as a result of processing the values of parameters of reliability during operation, as a rule, are compared with the corresponding values of the indicators for previous periods. This approach allows to carry out a quality assessment of the level of reliability in relation to previous periods. In this case, as stated above, do not take into account the impact on the statistical evaluation of the indicator of intensity of exploitation. Statistics of failure and faults are received in the unstable conditions of supervision, which greatly affects the accuracy and reliability of the evaluation. One of the specific objectives of the study is to improve the methodology of statistical reliability monitoring units ship equipment taking into account the impact of the intensity of operation and unstable conditions.

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ОСНОВЫ ВЫБОРА ТЕХНОЛОГИЧЕСКОГО ОБОРУДОВАНИЯ ДЛЯ УПАКОВОЧНЫХ ЛИНИЙ ПИЩЕВЫХ ПРОИЗВОДСТВ

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К приоритетным задачам научно-технического характера, решение которых создает условия для совершенствования процесса эксплуатации упаковочного оборудования, относится внедрение современных аппаратных средств, методов и программно-алгоритмического обеспечения параметрического контроля и диагностирования оборудования, а также внедрение средств и методов контроля технологических параметров в условиях реального времени. Критерий OEE (Overall Equipment Effectiveness) позволяет выявить потери и причины неэффективности работы. В результате определяется не только простой из-за поломок, но и потери из-за неэффективной работы оборудования, снижения производительности или ожидания поступления материалов. В конечном итоге OEE позволяет проследить, как влияют значения текущей производительности отдельной единицы оборудования на эффективность работы целого производства. Полученные в результате обработки значения параметров надежности в процессе эксплуатации сравниваются с соответствующими значениями показателей за предыдущие периоды. Такой подход позволяет проводить оценку качества уровня надежности оборудования.

Ключевые слова: *критерий диагностики, синтез, упаковочное оборудование, OEE (общая эффективность оборудования).*