Section: INTELLIGENT SYSTEMS OF MANUFACTURE

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IMPROVING THE EFFICIENCY OF INTELLECTUAL PACKAGING SYSTEMS

Abstract: *Production systems with elements of intellectual technologies can be found in various fields of production. To ensure the effectiveness of such systems, digital technologies are often used, which allow to create special databases for describing their state in functioning and to analyze data for identifying sources that lead to loss of efficiency. This article focuses on the construction of digital models for analyzing the production system of packaging, taken as an example. It is shown how data analysis is performed to identify critical elements in the production system.*

Keywords**:** *intelligent manufacturing system, packing automatic machine, intellectual production, digital models, digital technologies, system analysis*

INTRODUCTION, PROBLEM STATEMENT

It is difficult to imagine a user of a production system that would not want to make it more effective. The exploitation of production system is always accompanied by a number of emerging problems for improving of its efficiency, the most common of which are:

• increasing in production volumes on existing equipment,

• costs reducing in exploitation of existing equipment, etc.

The modern way of problem solving to increase the efficiency is to create intellectual production based on the usage of advanced information technology. It is already built a single approach to building an intellectual production system, which provides opportunities for increasing the production efficiency. In its creation it is monitored the transition from efficiency increasing at each stage of production separately to the optimization of production process in general. Providing the intellectual production efficiency is based on automated procedures for collecting and storing information necessary to track the revenues of raw materials, finished products, equipment and personnel – everything, that is used in production activities [1, 2, 4].

Summarizing the arguments of many researchers of modern automated production [3,6, 7], it can be argued that the production system becomes intelligent if, in problems solving of production, it adapts to work in external conditions that are changed over time, relying on the appropriate knowledge base. So, systems of automatic control (SAC) must be suitable for working with knowledge bases [5, 6], that is to become intelligent SAC. Since in the formation of a management program possible production situations should be taken into account, intelligent SACs should compensate for changes in external conditions by making certain changes in the control algorithm to achieve optimal performance parameters of the production system. Obviously, such a SAC should first of all assess the external conditions in order to make the necessary changes in the algorithm of functioning and also be provided model that describes the production situation at given moments of time, that is, the digital model of the production system.

MAIN ARTICLE

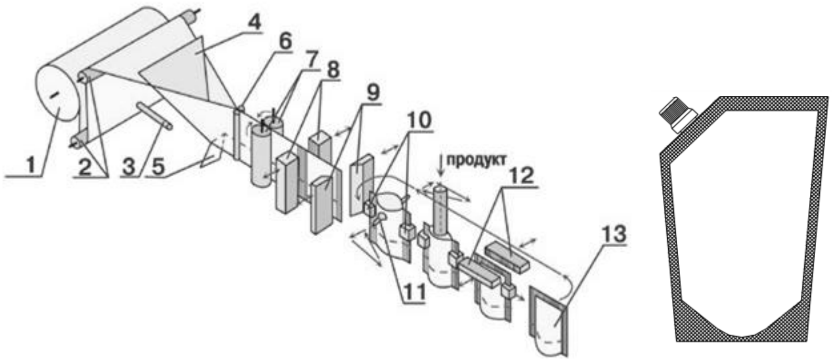
Principles of usage of digital models

The digital model of the production system is its "digital double", in the creation of which the most complete available knowledge about the production system is used. It allows you to get the right decisions quickly and to solve analysis problem of the production system behavior in different production conditions or the search for hidden patterns to identify critical elements in the production system.

The usage of digital models that describe a single production cycle involving exclusively machines and mechanisms to solve similar production problems is the implementation subject of digital technologies in production. Creation of digital models of production processes by transferring events from the real physical world to the world of models, as well as their usage for the development and adoption of control decisions, forms the so-called "digital production". This article focuses on the construction of digital models for analyzing the production system of packaging, taken as an example, but in practice this concept can be implemented for all mechanical processes, since all technological characteristics are the same.

Digital models for analyzing the production system of packaging

This definition implies that for the whole chain of stages of the packaging process (Fig. 1) should be information confirmation that the production system functions "as needed".



a) b)

Fig.1. *Technological scheme of paste packing in packages "doypack"* ***(a)*** *and a package doypack with a cork* ***(b)****, authors': 1-roll of film, 2- film unwrapping, 3-puncher, 4-pipe formation, 5-photosensor, 6,7- swaths, 8-longitudinal welding, 9-cutting, 10-package opening, 12- sealing of the package (in packages with the cork, between the cutting mechanism 9 and the mechanism of package opening*

10, there are a mechanism of corner cutting of the package 9-a, a mechanism of cork supplying 9-b and a mechanism of the cork welding 9-c – are not shown).

It was considered and recorded in the database of its simple for the period of its operation in real production conditions from 22.5.2016 to 22.5.2017 to study the sources of the efficiency loss of the multi-positional automatic machine for packing of pastes in packages like "doypack". The multi-positional automatic machine carries out the following technological transitions: film unwrapping from a roll, pipe formation from it, longitudinal welding of sidewalls for the formation of a package, its cutting, corner cutting of the package and welding into it a cork, filling the package and sealing it with welding (see Fig. 1) .

The model of the production system is based on the collection of data on the length of stay of packing automatic machine in an operational state and in idle states for various reasons. To simplify the construction of the model in such cases, a line or a complex machine is divided into autonomous units. The structure of the packing automatic machine is shown in Fig. 2. The usage of the sensors allows you to collect and transmit information quickly, without interruption, and most importantly, even from the most inaccessible places of machines with parts that work at high temperatures and high loads. At the same time, data collection is more accurate and faster, because instead of the engineer the information is read and transmitted by special sensors.

As you can see, a multi-positional automatic machine is a complex technical object. Its operation is described by a large number of parameters. For its processing, it is necessary to use a set of systems analysis approaches and methods of processing unstructured data of enormous volumes and significant varieties for obtaining results that become possible for human perception (large data or eng. BIG DATA.) Large amounts of data have hidden connections that are not always can be found by experts.

To solve the production problem of efficiency increasing of the multi-positional automatic machine, we can use the tools of applied system analysis and modern environments of data analysis for its operation, which allow us to turn the solution of the general problem into a "technological process", where the sequence and content of the design operations are clearly defined.

The scheme of work with large data is common to all digital production tasks and includes such stages:

- formulation of target indicators,
- data preparation (its coding, structuring, filtering, etc.);
- construction of models,
- checking of models quality,
- adaptation of the received results obtained to production needs

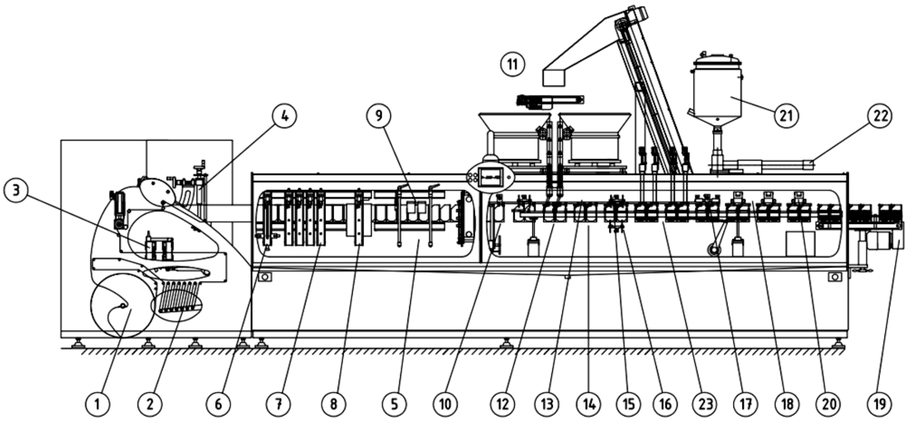


Fig.2 *Technological machine for packing pastes in packages "doypack", authors': 1-roll of film, 2-mechanism of unwrapping, 3-puncher, 4-forming triangle, 5- guides, 6- soldering iron of bottom with a drive, 7-mechanism of vertical welding, 8-mechanism of cooling, 9- corner stamps, 10- cutting mechanism (scissors), 11- a mechanism of cork supplying, 12- soldering iron of corks, 13-top stretcher with tweezers, 14-lower stretcher with tweezers, 15-top suckers, 16-bottom suckers, 17-mechanism of package stretching, 18-horizontal soldering iron , 19- conveyor, 20-cooling mechanism, 21-bunker with a product, 22-dispenser drive, 23-dispensers (4 pieces) with drive*

The first stage of a digital model construction is the definition of factors that influence on the state of production system and the construction of a hierarchical tree of influence on its efficiency. Tree of factors are factors organized in the form of a cause-effect diagram - a tool that allows you to identify the most significant reasons that affect the last result. In this way, you can get to the primary reasons, the elimination of which will most significantly affect the problem solution of increasing the efficiency of the equipment use.

To ensure coverage of all aspects, you can use the Ishikawa diagram or other methods to systematize the sources of idle time in the production system. According to the generally accepted method, the idle time is divided by us into three classes:

1. own idle time, arising in the machine as a result of its implementation of the work process;
2. organizational and technical idle time caused by the influence of the environment of the machine functioning conditions;
3. idle time due to re-adjusting the machine.

The second stage is the data preparation. Here it is necessary to identify the most important reasons to manage. To do this, each parameter must be evaluated and identified. Some parameters had to be taken as irrelevant on the basis of obvious arguments. Idle time, caused by various reasons of operation stopping, and also by failures in separate nodes and mechanisms of the machine, is given in Table 1.

Stage 3 – preparation of a digital model of operation of a multi-positional automatic machine. Excel files are used to enter and display information stored in a specialized database, the extract from which is given below (table 2).

Stage 4 - The using of model for increasing the efficiency of production. The problem arises if the value of efficiency does not suit us. To solve the problem (to improve the production system) – means to eliminate the reasons that lead to decrease in its efficiency. Obviously, there are so many reasons, and eliminating each of them is a very troublesome and costly task. The logic of system analysis involves the identifying the most significant reasons that lead to a problem, and the concentration of effort on them.

Table 1

Classification of sources causing idle time of packing machine, authors'

Classes of idle time	***Subclass***	***Idle time group***	***Subg.1***	***Subg. 2***	***CODE***
1. Own idle time-machine failures		1101. Pomp of product supplying			***11010***
		1102. Mechanism of film drawing			***11020***
		1103.Vibrbunker			***11030***
		1104. Mechanism of cork catching			***11040***
		1105. Mechanism of cork supplying and inserting			***11050***
		1106. Mechanism of cork soldering			***11060***
		1107. Mechanism of vertical soldering iron			***11070***
		1108. Dispenser with nozzle			***11080***
		1109. Cooling mechanism with a thermal sensor			***11090***
		1110. Vacuum pump			***11100***
		1111. TEN and thermal sensor			***11110***
		1112. Photosensor of			***11120***

		marks			
		1113. Vibrbunker of corks			***11130***
		1114. Printer			***11140***
		1115. Mechanism of scissors			***11150***
		1116. Mechanism of package opening with suckers			***11160***
		1117. Corner stamp			***11170***
2. Organizational and technical idle time	***21. Power breaks***	211. Lack of electricity			***21100***
		212. Lack of compressed air			***21200***
	22. Breaks in the supplying of materials	221. Lack of film	2211. Delay	Roll changing	***22110***
			22120. Low quality film	Disassembly of film	***22121***
				Corrugated film	***22122***
				Extra switching-on	***22123***
		222. No product	2221. Product delay		***22210***
			22220. Low quality product	Cold product	***22221***
				Hot product	***22222***
		223. No corks	2231. Delay of corks		***22310***
			2232. Low quality corks	Sharpening on the cork	***22321***
				Distorted	***22322***
	23. Staff expectation	231. No staff			***23100***
		232. Staff mistakes			***23200***
	24. Incident	241. **Unpredictable**			***24100***

		problems			
3. Idle time while reconfiguring	31. While changing the film producer				***31000***
	32. While changing the dose of the product				***32000***
	33. While changing the product				***33000***
	34. While changing the package type				***34000***

Table 2

Extract from the database of the operation of a multi-positional automatic machine in real production conditions from 22.5.2016 to 22.5.2017, authors'

№	**Class of idle time**	**Group of idle time**	**The reason of idle time**	**Code of idle time**	**Duration, min**	**Starting**	**Comment**
1	1 - Own failures	1102 - Mechanism of drawing	Tightening of film in a triangle	11020	3,00	22.05.20 2016	During the change
2	1 - Own failures	1102 - Mechanism of drawing	Replacing the spring of the tweezers	11021	3,00	22.05.20 16	Packets were sagged
3	1 - Own failures	1107 - Mechanism of soldering iron	Unplanned cleaning of soldering iron	11070	9,00	25.05.20 2016	Unplanned washing of machine, the car was flooded
	...	...	...	...	...	...	...
123	1 - Own failures	1102 - Mechanism of drawing	Replacing the spring of the tweezers	11021	9,00	26.05.20 2016	Packets were sagged. And washing of machine ,
124	2 - Org-tech idle time	2221 - Lack of product	Lack of product	22210	35,00	27.05.20 2016	No steam. Oversealing of the central condensate wire.
	...	...	...	...	...	...	...
417	1 - Own failures	1107 - Mechanism of soldering iron	Unplanned cleaning of soldering iron	11070	9,00	23.05.20 2017	

To analyze the reasons of the efficiency loss of the production system, we use aggregation of the data contained in the database. It will allow describing the generalized (aggregate) parameters of the system by formation of the standard summary tables in the Microsoft Excel system. Such aggregate parameters more precisely describe the target properties of the production system.

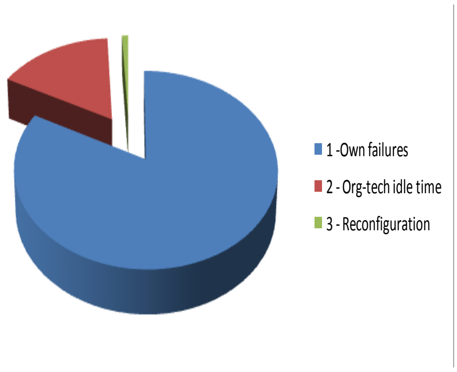


Fig.3. *Determination of the importance of idle time, affecting on the efficiency loss of the packing machine (total 5627 min per year), authors'*

Since the model of the production system, based on the data collection about the duration of stay of a multi-positional automatic machine in different states, then, creating aggregate objects, you can determine its efficiency, as a part of the useful time. To set the aggregation rules in the Microsoft Excel system, it only needs to specify which criteria should be in aggregate objects.

Fig.3 shows the classes of idle time. According to the results shown in Fig. 3 it can be concluded that the main source of idle time during the machine exploitation is its unreliability, caused by frequent failures of machine mechanisms. To analyze the major sources of unreliability, we will make a ranking of the causes of failures (Fig. 4).

The sequence of aggregation and decompositions ends when the critical terms of the system description are discovered - the parameters that influence on the unsatisfied value of the target property of the system. It is necessary to focus on improving and stabilization of these parameters at carrying out of the following stages of system analysis.

The reviewed digital models describe the conditions of exploitation based on the results of events that have already occurred. However, the effectiveness of such use of digital models, despite the possibility of analysis of production and the identification of necessary reasons for correction, has a drawback. Since equipment at many production enterprises operates day and night, then its unexpected stop can lead to a lot of losses. To prevent this problem, we developed a mathematical model for defining of controlled parameters and features that describe the functioning of a technological automatic machine, which allow us to determine the current state of the machine and to predict the necessary preventive actions of service [8].

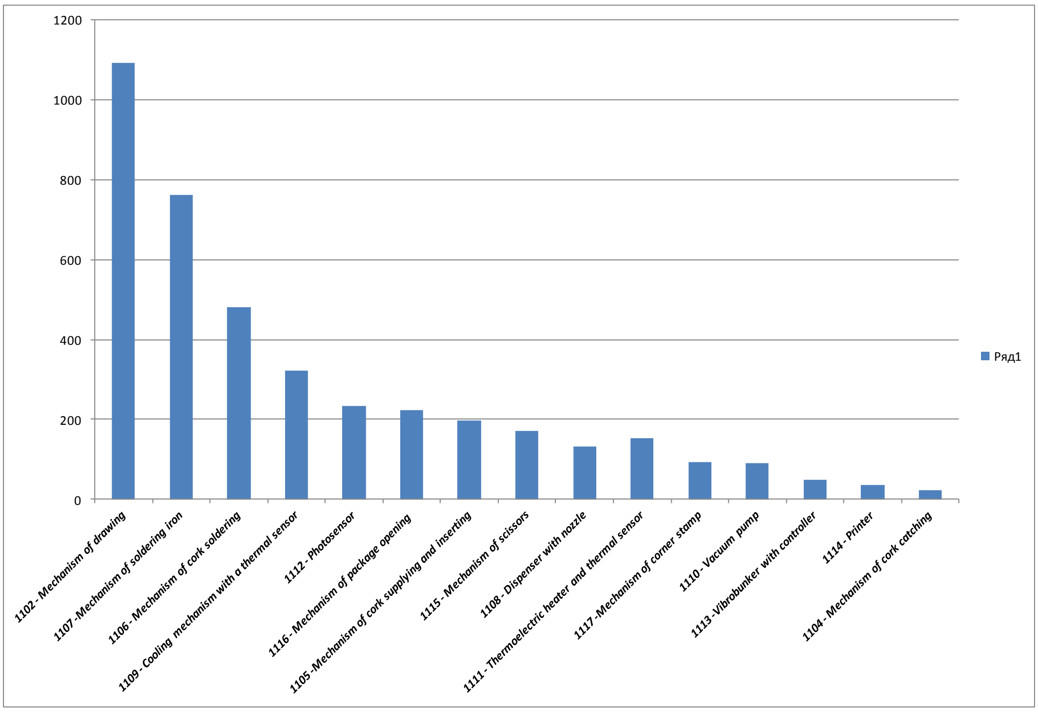


Fig.4. *Types of idle time in machine mechanisms, authors'*

Table 3.

Aggregation of idle time in a machine, authors'

Idle time	Duration, min	**Idle time**	Duration, min	**Idle time**	Duration, min
1 - Own failures	4219	1115 - Mechanism of scissors	170	**2 - Org-tech idle time**	919
1102 - Mechanism of drawing	1093	1108 - Dispenser with nozzle	133	211 – Lack of electricity	173
1107 - Mechanism of soldering iron	761	1111 - Thermoelectric heater and thermal sensor	152	2221 - Lack of product	295
1106 - Mechanism of cork soldering	482	1117 -Mechanism of corner stamp	94	2222 - Low quality product - cold	207
1109 - Cooling mechanism with a thermal sensor	322	1110 - Vacuum pump	90	23 - Staff expectation	63
1112 – Photosensor	233	1113 - Vibrobunker with controller	50	24 - Incident	181
1116 - Mechanism of package opening	224	1114 - Printer	37	**3 - Reconfiguration**	49
1105 - Mechanism of cork supplying and inserting	196	1104 - Mechanism of cork catching	10	31 - When film changing	49
				In total	***5627***

Lately, researchers from the University of Portsmouth in the UK have used an artificial intelligence to predict when machines need preventive service. The diagnostic system using a branched system of sensors examines how machines work, and uses this information for accurate predictions when it will be necessary to perform technical service.

CONCLUSIONS

The main attention in this article is devoted to the construction of digital models for analyzing the exploitation conditions of the packaging process, which was shown as an example, but this concept can be implemented for all mechanical processes (processing, assembling), since all its technological characteristics are the same . Moreover, since the processes of packaging are mechanical processes, during which several elements are periodically processed and merged (that is, the product is often checked and controlled after each stage), this approach can be automatically extended to cover the processes of assembling as a whole .

Obviously, the direction of improving of digital technology in automatic production should be predictable for the future states of the production system. If you place sensors in sensitive details and mechanisms of a machine that are detected in the efficiency analysis of machine exploitation, for example by ranking, as shown in Fig. 4, then the special software will be able to monitor and analyze signals and warn technicians about the malfunctioning or the need to change the mechanism, or its detail that are in critical state. Such approach is already developing in real production conditions, which is confirmed by the fact that modern packaging machines already have 120-150 sensors that control the machine functioning.

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