PRINCIPLES OF DESIGNING AND DEVELOPING INTELLIGENT MANUFACTURING SYSTEMS OF PACKAGING

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Annotation: *Manufacturing facilities employing the elements of intellectual technologies can be encountered in various industries. The given paper provides examples of intelligent devices of manufacturing packaging systems. It shows how to maintain operational performance in case of unforeseen changes in the properties of an intelligent manufacturing system by changing the operation algorithm, changing the program behavior or searching for optimal or effective solutions and states during operation.*

KEY WORDS: INTELLIGENT TECHNOLOGY, EXPERT SYSTEM, TECHNOLOGICAL COMPLEX, ADAPTIVE MANAGEMENT

1. Introduction

The historical experience of industrial development demonstrably shows that the traditional system of industrial manufacture is not capable of ensuring a stable and harmonious development of the national and world economy. It is now becoming apparent that large-scale manufacturing, designed for the stable production of a narrow range of products, is becoming obsolete in the face of growing competition. In order to maintain science-based industries it is necessary to develop adaptive manufacturing systems with a high level of flexibility to the changing market demand. Industrial technologies have become predominantly oriented towards flexible production with a wide use of automatic machine systems. We are now on the verge of the fourth industrial revolution, which unites computer-aided manufacturing and elements of artificial intelligence. Thus, a new element - the artificial intelligence system – is added to the chain – the computer-aided manufacturing system and the electronic computer system. Such a combination has taken the name of an intelligent manufacturing system, and its elements – intelligent technologies and intelligent manufacturing facilities. The intelligent system is understood as an adaptive system that allows executing programs of expedient activities to solve the assigned tasks on the basis of a specific situation that is currently developing in their environment. The advent of a new era in industry is characterized by the fact that the equipment of the future will consist of intelligent devices capable of transmitting information, reaching local solutions and communicating among themselves.

2. Prerequisites and approaches for the task

In this connection, the works on creation of integrated adaptive manufacturing systems and intelligent control technologies of the next generation occupy a dominant place in the scientific development of industrial manufacturing tasks. Today, this direction of research has evolved into a cause celebre in response to the real needs of the industry and is now being carried out by large international consortia on the initiative of the governments of the leading industrialized countries. For instance, **"Industry 4.0"** is the German strategic initiative for taking the leading role in the field of industrial information technologies, which are currently inverting the industrial sector.

Such a transition requires for the necessary element - intelligent devices in the equipment that can locally perform certain functions and exchange data with all stakeholders of the manufacture.

3. Principles of developing intelligent production systems

The range of tasks solved by intelligent systems includes the tasks that, as a rule, have the following features.

1. In these tasks, an algorithm for solving them is unknown (they are called intelligent tasks);
2. In such tasks, there is a choice.

Since there is no algorithm for solving intelligent tasks, it is proposed to make a choice between many variants in a context of uncertainty. Thus, it is obvious that freedom of choice is an essential feature of intelligent tasks.

The goal and control actions are formed in such systems on the basis of knowledge of the external environment, control object and on the basis of modeling situations in the actual system.

Systems of artificial intelligence with databases and knowledge pools are aimed at solving applied problems. Among them, an important role is played by industrial-purpose expert systems of artificial intelligence, which are already used today, for example, to develop recommendations for the selection of components and the layout of flexible automatic manufacturing.

The main challenge of assessing the effectiveness of production processes on the basis of probabilistic dependencies is the ambiguity of the law of distribution of the occurrence probabilities of certain events. And this is due not to the lack of sufficient statistics, but to the limitations of the methods of classical probability theory themselves, the use of which is permissible when events are repeated under identical conditions.

Now there are expert systems (ES), or knowledge-based systems, without which it is impossible to imagine any modern intelligent technological system [1]. Therefore, under the artificial intellect of manufacturing facilities, we will mean the algorithmic and software support of their adaptive control systems, which makes it possible to automate technological operations of an intellectual nature.

Flexibility of manufacturing systems, especially in multiproduct manufacture, is ensured by their structure in the form of a complex combination of machine tools with numerical program control, other process equipment and industrial robots controlled by microprocessors, with computer-aided manufacturing systems.

According to experts, the optimal development strategy is the decentralization of intelligent equipment systems. This means that it is necessary to “provide with intelligence” every component of an electrical or hydraulic system, rather than creating a single intelligent automation system. Thus, the basis of equipment management is a decentralized intellectual model, which intends to make all sensors and executing devices intelligent. Intellectual production implies a shift from centralized production to decentralized production. Production machines no longer simply “pass” the product through automatically - the product interacts with the machine, tells it what to do.

The basis of intellectualization of such flexible technological systems is the elements of the lower level of the structure - the functional elements of flexible production modules and robotic technological complexes. The allocation of the active functional elements of the technological system as the main resource for managing distributed intelligence and its use for efficient solution of the task of coordination of operating actuators essentially simplify the structure of the control system, increase its speed and reliability. In order to implement the concept of intelligent production, simple components such as functional modules and control units in machines and systems must be transformed into intelligent devices that efficiently transfer data in real time.

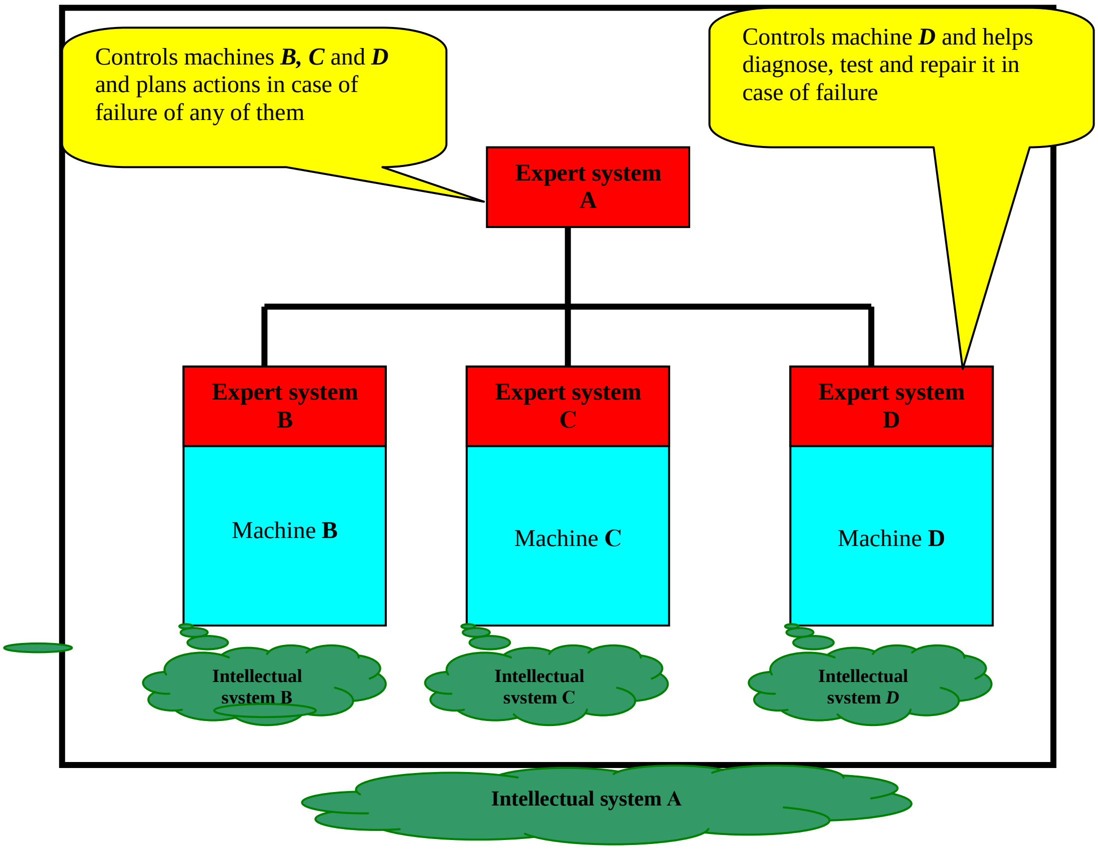

Fig. 1. *Hierarchical intelligent diagnostic system*

Products manufactured under the conditions of intellectual production will "inform" by themselves the equipment as to how, where and by whom they should be manufactured.

The utilization of intellectual production systems allows to improve significantly the quality of products due to automating the majority of operations, including those that until recently were considered to be unsuitable for full automation, for instance, high-precision adjustment of technological equipment [2].

Modern MES-systems (MES - Manufacturing Execution System) allow creating quit detailed production schedules, for instance, for each type of work on each machine, with the appointment of a particular worker to a particular machine at a certain point in time. Using RFID technology, such systems allow obtaining any necessary information, recording the exact state of each work and each resource.

The data obtained from the diagnostic system can be used to detect a regular delay in the implementation of transitions, overloading of equipment components and timely elimination of the issue. This helps to increase the speed, accuracy and repeatability of operations, which increases the speed of the production process and reduces the number of failures. This built-in intelligent diagnostic system simplifies traditionally complex control methods and improves the reliability of the machine. It becomes possible to combine various elements: functional modules, loading/unloading mechanisms, sensors and actuators of control and signaling devices and programmable logic controllers (PLCs).

A pragmatic approach gives satisfactory results in the case of modeling relatively simple, well-organized technical systems. With regard to the analysis of complex, weakly structured systems, the use of previously obtained formalized knowledge and methods of solving analytical problems, such approach becomes inefficient, because with their help it is impossible to find an optimal solution to the emerging issues.

4. Application of modern technological equipment with elements of artificial intelligence in packaging production

One of the disadvantages of equipment creating process is the traditionally adopted sequence, when the mechanical part is initially constructed, then for the developed mechanics a control system is selected that provides the required laws of movement and technological processing modes. In doing so, we obtain a system in which the optimal but separately projected parts do not always turn out to be optimal for the whole system as a whole. Thus, the main trend of development of modern technological equipment is the unity of mechanics and management.

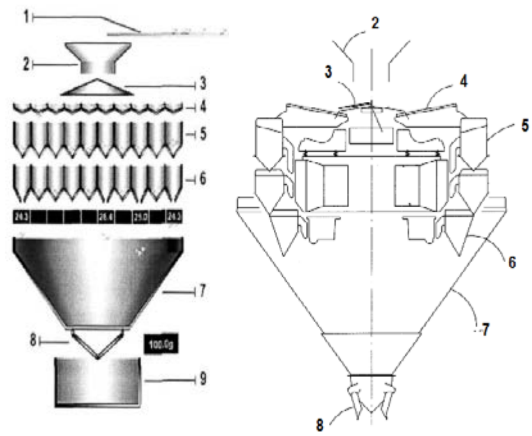

Fig. 2. *Simplified structure diagram of the combination weight batcher [3]*
1 - loading device, 2 - front bunker, 3 - distributor, 4 - vibrating feeder, 5 - pockets, 6 - weighing cells, 7 - bunker, 8 - dampers, 9 – packing machine (no connection to batcher design).

Modern high speed computer technology allows a new approach to the creation of a technological machine. The control system in conjunction with the information sensors is able to correct the "disadvantages" of the mechanical part of the technological machine.

Therefore, the technological machine must be considered as a single system, including mechanical part, technological process and control system itself.

Optimization of the weight during dosing (using the weight selection algorithm) (Fig.2). The work of the multihead weight batcher is as follows: during the weighing process, the computer calculates all possible combinations between the obtained values and chooses the one that is closest in its value to the given dose. After that, the content of the cells, whose indices entered the selected combination, are dropped into the packaging machine. With the use of such combined weight batcher, the products are packaged in a container without significant deviation of the package weight from the specified one. Also such dosing algorithm allows to significantly increase the productivity of the weight batcher itself. With a large production volume, the high cost of the multihead weight batcher is compensated by high productivity and reduced losses for overexpenditure of product.

Optimization of the periods of corrective adjustment of automatic devices (analysis of change in the quality parameter and selection of corrective adjustment points). Applicable in the case where the operation of the technological system can be characterized by such a quality parameter of the product, the value of which is easily measured and controlled during operation. Such parameters may be one of the exact dimensions of the part during mechanical processing, or the weight of packages during automatic dosing, etc. Therefore, this method is also called the product quality statistical regulation method.

The method is based on in-line analysis with the help of instant samples of the researched indicator of the accuracy of technological complex. The method assumes constant monitoring of statistical parameters of instant samples (for example, mean absolute and mean square deviation), which allows timely warning of the appearance of rejection by determining the moments of equipment corrective adjustment. And the system determines the moments and values of the corrective adjustment by itself.

The algorithm of the statistical regulation plan provides for determination of the sampling periods and the sample size for the given values of the control limits. When the method is carried out, the nature of the influence of systematic errors is also determined, leading to a disruption of the normal course of the process.

Smart cassette for details. With robotic loading, the parts are installed on the cassette pins by an industrial robot. In case of inaccurate delivery of a detail-glass to the cassette's pin, in the control system of the robot model "Electronics NC-TM-01" there is a three-fold repetition of the attempt to install the part. Repeated execution of the installation of the part can be carried out under the same conditions as that which led to failure using the probabilistic principle of non-repetition of the same combination of elementary errors that led to failure, or can be performed with an adjustment of the reciprocal position of the receiving element and the part.

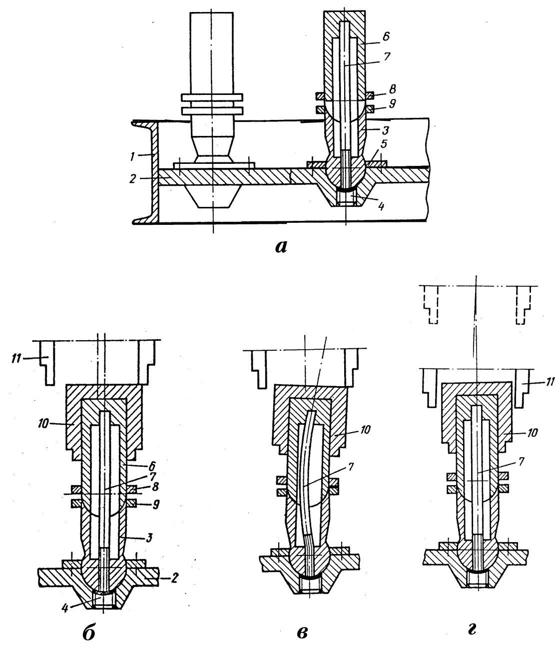

Fig. 3. *Receiving element of the smart cassette with auto-correcting when loading the part*

A further increase in the probability of successful coupling of the detail to the cassette pin was achieved due to using cassettes with pins changing their position in the direction of reducing the misalignment error of the pin with the position of the detail. The developed version of the smart cassette, (Fig. 3) is based on the use of repeated movement of the delivery of the detail for auto-correction. The detail 10 (Fig. 3, a) is located on the receiving pin 6 of the cassette. If the gripper axis 11 does not match with the axis of the part, the gripper bump into the end of the detail (Fig, 3, б). The pin 6 and the support 3 with the lower spherical end are connected to each other by the elastic element 7, they are returned under the influence of the grip action in opposite directions of the contact of ring stops 8 and 9, which can be adjusted on the pin 6 and the support 3. After retraction of the gripper 11 without the detail, the elastic element 7 is straightened and returns the pin 6 relative to the support 3 in the direction of the grip axis, reducing the misalignment error (Fig 3, в, г).

4.1. Levels of integration of intelligent production systems

Thus, the usual software technological complex, operating directly with details or blanks, is the lowest link in the intellectual production complex. It follows that the intellectual production system can be conditionally divided into two modules - "mechanical" and "intellectual". As a rule, a mechanical module is understood as either an automated robotic complex or a certain flexible production system.

As the main classification feature in the intellectual production system (Fig. 4), it seems reasonable to accept the level of functional complexity of the constituent elements.

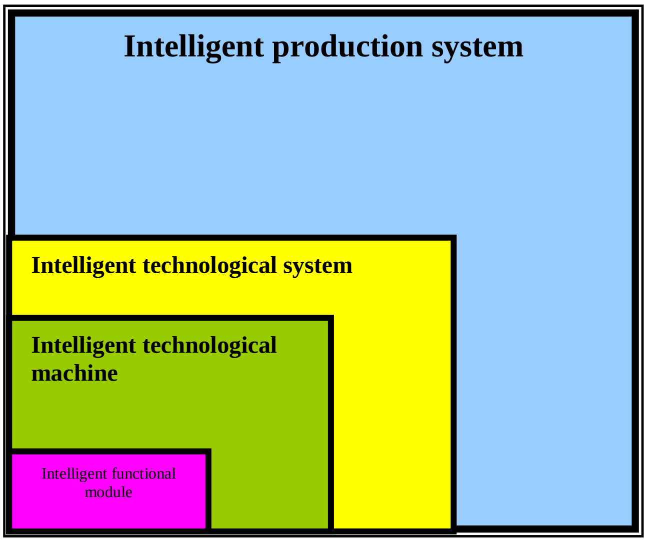

Image. 4. *Integration levels of an intelligent production system*

Intelligent elements of the first level are functional modules that perform one simple function, but with the option of implementing it depending on external influences (signals from products, neighboring modules or a higher-level control system). A typical example of an element of the first level can be a combinatorial dispenser, or a cassette for details with a changeable position of the receiving pins.

5. Conclusion

One of the essential requirements of intellectual production is the use of data transmission and analysis technologies. The use of RFID technology for this purpose has high perspectives, since it will allow the machines to independently report information about their condition, and its components will automatically warn about the timing of maintenance or repair. To implement such concept, as preliminary studies have shown, details, machines, nodes, controls should be able to exchange information with each other and with the personnel.

We have shown that currently there are many complex devices with their own electronics that meet these requirements. Such devices are common in the packaging industry, which develops quite dynamically. However, a large number of simple components, such as operating elements, moving and feeding mechanisms, signaling devices, switches, sensors and actuators, are for the most part not included in the network of the production line.

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