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 development and use of advanced information technologies at all levels of manufacturing management allows you to go to the intellectual of the technological equipment. Any manufacture task, for which there is an unknown algorithm for its solution, can be attributed to the intellectual. To solve this problem it is necessary to create an appropriate knowledge base and apply mean of artificial intellectual [1, 2, 4, 7].

Summarizing the arguments of many researchers [3,6,7], it can be argued that the manufacturing system becomes intellectual, if decision tasks of manufacturing, it operates without having an exact algorithm for solving the problem. It adapts for work in external conditions varying with time, based on the appropriate knowledge base that allow you to create the adaptation algorithm.

2. Prerequisites and approaches for the task

The development and use of advanced information technologies at all levels of manufacturing management allows you to go to the intellectual of the technological equipment. Any manufacture task, for which there is an unknown algorithm for its solution, can be attributed to the intellectual. To solve this problem it is necessary to create an appropriate knowledge base and apply mean of artificial intellectual. Summarizing the arguments of many researchers, it can be argued that the manufacturing system becomes intellectual, if decision tasks of manufacturing, it operates without having an exact algorithm for solving the problem. It adapts for work in external conditions varying with time, based on the appropriate knowledge base that allow you to create the adaptation algorithm. For this automatic control systems (ACS) must be suitable for working with knowledge bases, that is to become intellectual ACS (Fig. 1).

3. The features of the intelligent production systems

It follows that intellectual manufacturing system can be divided into two modules - "mechanical" and "intelligent".

As rule, under the mechanical module refers to flexible manufacturing system that implements the physical actions on product and has potential capabilities to adapt when changing function conditions.

Intellectual module of intellectual manufacturing system should include knowledge base and provide adjustments of program functioning when changing external conditions. It allows you to modify, based on the use of artificial intelligence as parameters of the functioning of intellectual manufacturing systems, and their structure.

Combining mechanical and intelligent modules provides getting intellectual flexible manufacturing system (IFMS).

First intellectual ACS, what combining the methods of traditional systems of automatic control and knowledge engineering, became expert systems (ES). The simplest intellectual ACS can, for example, consist of a conventional ACS and base of productive rules.

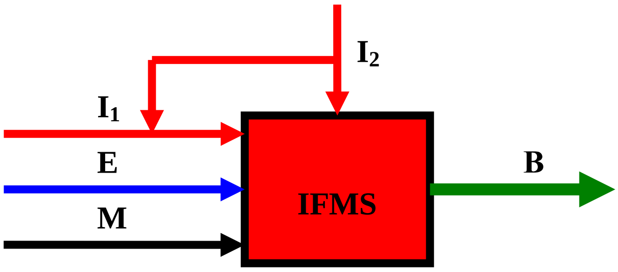

Fig. 1. *The scheme of interaction of flows in M – material flow, E – energetic flow, I_1 – information for management, I_2 – information for organizing the functioning of the IFMS, B- product*

Since the formation of management program must take into account possible manufacturing situations, the intellectual subsystem ACS must compensate for the change external conditions by making some changes in the management algorithm to achieve the optimal parameters of the functioning of the IFMS. It's evident, that such ACS must first of all, evaluate the external conditions in order to make the necessary changes in the algorithm of functioning. Therefore, intellectual ACS implements three management functions.

1. Identification of the manufacturing system, which consists in obtaining an estimate of the instantaneous quality of the process of its functioning by defining some indicator, which can be compared with its specified value.

2. Decision making, which is the search direction changing the functioning program of IFMS in the direction of improving the quality of the production process by changing its structure or modes.

3. Setup, which involves a physical or mechanical change of algorithm the functioning of IFMS.

Functional interaction of processes in of IFMS is shown in Fig.2.

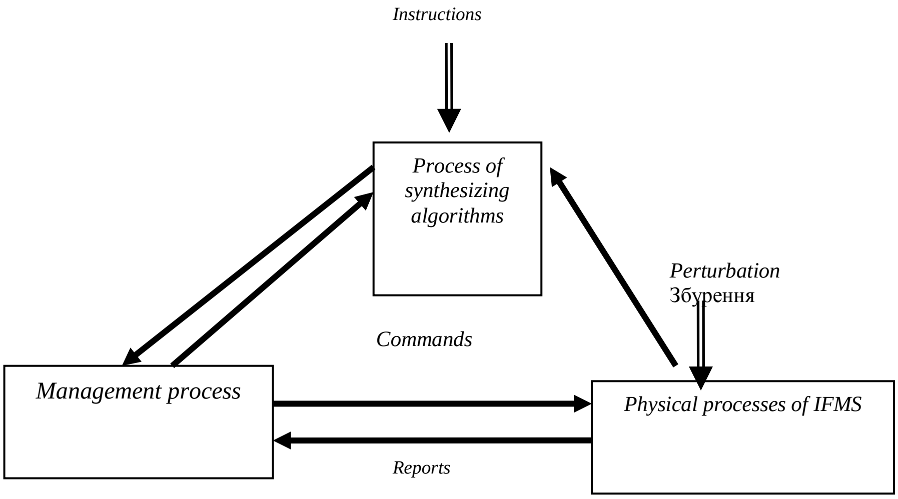

Fig. 2. *Processes of IFMS*

For implement these processes the structure of IFMS includes the executive subsystem, the subsystem of automatic control and intellectual (creative) subsystem (Fig.3).

for example, an expert system condition diagnosis of the machine and adjust the cutting conditions depending on the sensor readings

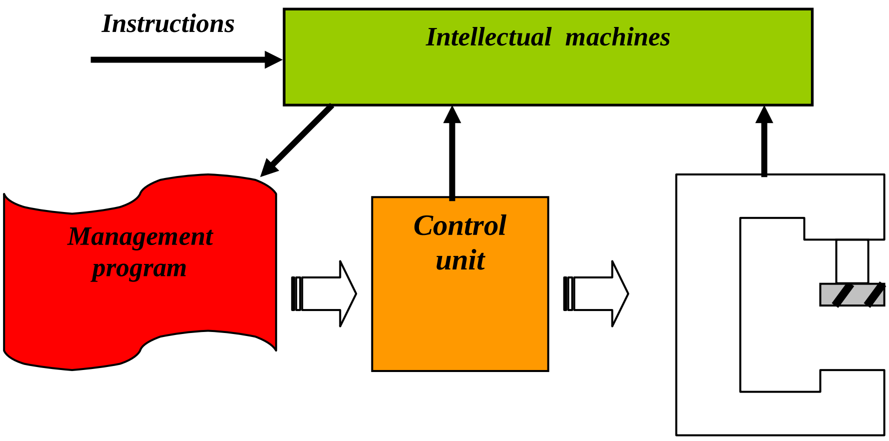

Fig. 3. *Structure of IFMS*

The **executive subsystem** of IFMS implements a physical process that needs to be automated.

The automatic control subsystem creates at its output the control commands of IFMS and signals IGUS and visualization signals depending on the results of reporting on the physical process and the results are consistent with the specified instructions.

Intellectual subsystem provides the formation algorithm of functioning depending on the influence of external (for example, changing a production task, the use of other semi-finished products, etc.) or internal (for example, failure of some mechanisms) factors.

For example, the intelligent flexible manufacturing module (IFMS) on the basis of CNC machine includes an executive part actually the machine and its basic mechanisms with drives soft ware management system and intelligent subsystem.

The executive system of the CNC machine implements technological operation from the conversion the work piece in the processed detail with the commands given control system. Thanks to reporting of executive system (instrument position, moving speed, the resulting size after processing, etc) the control system monitors the technological elementary operations. In addition to exchange of commands and reports system performance, the control system communicates with external systems (user, operator, etc.), receiving instructions and reporting back for help with a light or sound means. For this, in the structure of the machine is provided,

Since the formation of management program be aware account of possible production situation, then the intelligent subsystem ACS must compensate for changing external conditions by making of certain changes in control algorithm to achieve optimal performance characteristics of IMS. Apparently, such ACS must, first of all, to evaluate the external conditions in order to make the necessary changes in the algorithm of functioning. Intelligent functional diagram of ACS is shown in Fig.4.

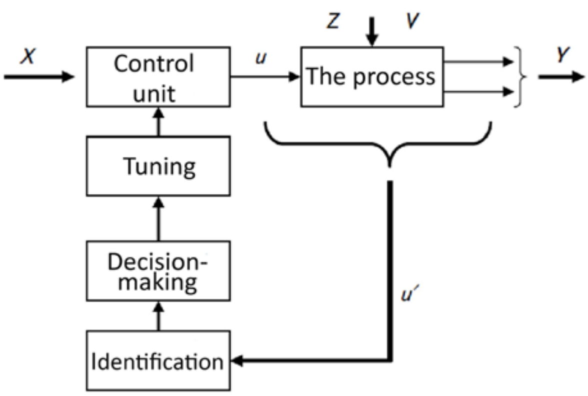

Fig. 4. *The functions of the intellectual control system of IFMS*

On technological process is influenced by external conditions **Z** (random disturbance) and **V** (change of production tasks) that changing. The control system determines the current values of input **X** and output **Y** of system parameters and determines the quality of the process **u'**. The decision about changes in the establishment **u** (reorganization of the algorithm operation and technological regimes), which are necessary to ensuring the quality of functioning of a technological machine.

In the solution of intellectual tasks, the system operates without accurate algorithm for solving the problem. Tasks associated with search algorithm to solve them, will be intellectual. Then any task, for is unknown the algorithm, will be referred to the intellectual, for which it is necessary to use the tools of artificial intelligence. As see, the intellectual tasks have two distinctive features:

- using of information in symbolic form (words, symbols, drawings), what distinguishes artificial intelligence systems from traditional computer systems, that processing only numerical data;
- availability of choice - the absence of a decision algorithm determines only those, that it is necessary to make a choice between many of their variants.

The main feature of intelligent systems is that, they are based on knowledge, or rather, on some of their performance. Knowledge here is understood as saving (using a computer) information, formalized according to some rules, which computers can use with logical deduction by certain algorithms.

Technological process design - is the creation of functional description the technological complex. If this description is created from known operations, then the technological process is formed by synthesis. The synthesis of technological process the question is solved number of technological operations, their level of concentration, consistency of execution. To expand the field of search variants of technological process it is necessary to generate the greatest number of possible variants of its structure. For creation of ES, which can carry out synthesis technological process with changing the route for different operating conditions of IFMS, need to create a knowledge base, which defines the sequence of processing of surfaces of details and type of necessary equipment. The results of this analysis will set the set of possible variants of processing routes. It is desirable in the first step is to carry out optimization of the synthesized technological process.

Show by example, how the building of knowledge base and model, which includes a plurality of alternative processing routes. Let task is processing the details made of cast iron – housing support (Fig. 5).

The following machines are located on the site:

• CNC lathe,
• long,
• vertical milling,
• CNC horizontal milling
• CNC drilling
• CNC boring.

In case of failure or busy processing another part, any of the selected machine tools, in of IFMS should be changing the processing route.

Knowledge base formation. For a formal definition the sequence of creating surfaces, let's introduce the concept of a binary precedence relation π. Consider, that in more general case, on sequence of the creation a product at formation its quality parameters influence the functional, design and technological constraints, which allows it possible to distinguish three groups relation of anxiety, namely:

• *functional precedence relations*, which are imposed by the conditions of operation of the product;

• *design precedence relations*, which are imposed by the conditions of spatial location the details and the individual surfaces in product design;

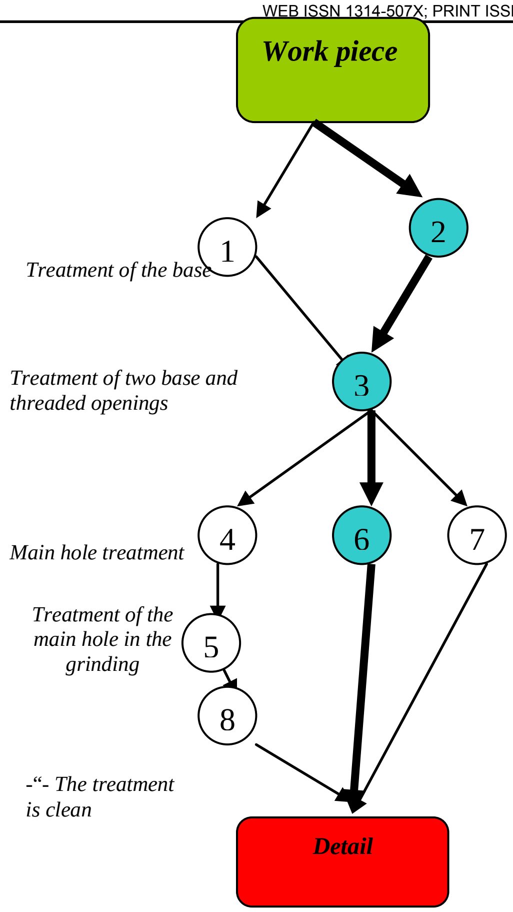

Fig. 5. *The graph of the Gπ forward is for the case handling options: 1- vertical extended; 2- vertical milling; 3- drill; 4- horizontal milling; 5 - drill; 6- turning; 7- boring; 8- prolonged*

• *technological precedence relations*, which are imposed by the conditions of manufacture of a product.

Determine the causal precedence relations of structural elements of the product graph Gπ or its matrix Mπ. The precedence matrix is constructed as follows. At the intersection of the i-th column and j-th row is a unit, if the i-th constructive element of the previous j-th, or zero otherwise. The matrix of causal relations will form:

Each element of the matrix satisfies the following requirements:

$$d_{ij} = \begin{cases} 1 - & \text{if the i-th structural element should be created before the j-th;} \\ 0 - & \text{otherwise.} \end{cases}$$

Because the constructive elements of the product are implemented by appropriate technological transitions or operations, the causal relationships between these elements determines the precedence relation between technological transitions or operations.

To determine the total number of such links for each of the surfaces, which is necessary to process, sum the unit in each row of the matrix, and the amount is written in the column ***BO,*** which indicates the degree of technological dependence of the processing of this surface from other surfaces of the part. Summing unit in each column of the matrix, write their sum, which characterize the technological degree of imitation of the surfaces, that their influence on the processing of other surfaces.

Determining the processing sequence will be guided by the following.

1. The first treated surface is processed, which requires no pre-treatment of other surfaces, that is, the column dependence ***BO*** zero value (no precedence relations).

2. When processing this surface all the connections are forwarded, which are in the column of the surface subtracted from

the values, shown in the column total degrees of dependence ***BO***. The resulting values describe the new state of the part after the first stage of processing – ***B1***. To determine the next surface for processing the repeating stage 1, whereupon, the procedure is repeated.

3. In the presence of multiple surfaces with zero degree of dependence, they can be processed in one step.

We got with help of formalized procedure, the sequence of technological transitions surface treatment details, which creates three stages of processing, specified by the precedence graph Gπ.

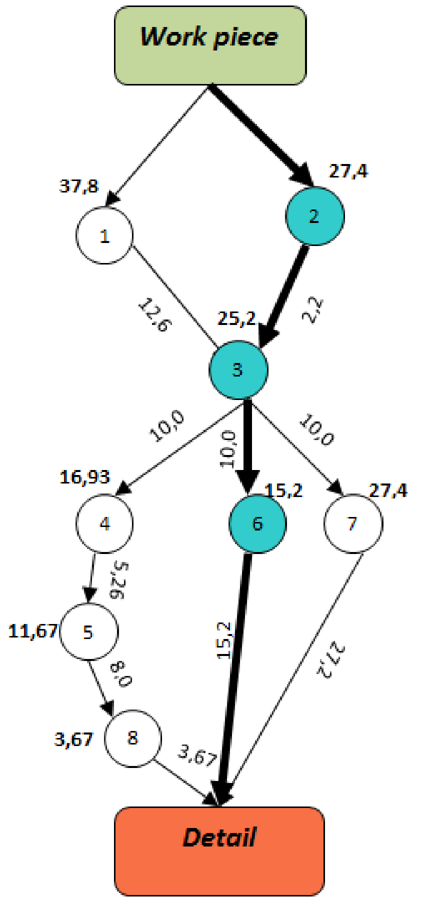

Fig. 6. *Model of the set of routes for handling the support casing*

Marking vertices of the graph is performed, starting from the last operation, as follows: on each vertex, note the minimum value of technological cost, which meets the minimum path to it from the end of technological process (vertex 2-3-6). The value of other ways that have the highest total the cost of technology, down. After the reverse run graph model minimum path is remembered and celebrated. The resulting sequence of operations 2-3-6 is the optimal technological process, which ensures the lowest cost of processing.

In order to realize the concept of intellectual production, the main components of IFMS (machines, their functional modules and control units in the machines, etc.), must be converted into intellectual device with systems of diagnosis, that are real-time transmit data about their state (healthy - faulty, busy – free, etc.). Obtained from the system diagnostics data can be used for identify periodic delays in the execution of transitions, reloading components equipment and timely resolve the problem. This helps to improve speed, accuracy and repeatability of the operations, which increases the speed of production process and reduces the number of failures.

From the knowledge base for IFMS processing the housing of support. Complete the knowledge base, according to the following rules.

Rule № 10. The work piece is fed to vertical milling machine 2 and, if he is free and healthy, basis processed.

Rule № 20. If vertical milling machine is busy (repairs or perform other operation), then the work piece is fed to a prolonged machine 1 and basis processed.

Rule № 30. If a long machine is busy, the process stops before the dismissal of the machines 1 or 2.

Rule№ 40. The work piece is fed to the drilling machine 3 and, if he is free and healthy, which processes 2 basic and one of the threaded holes.

Rule № 50. If machine 3 is engaged, the process stop.

Rule № 60. The work piece is fed on the lathe machine 6 and, if he is free and healthy, processing two the ends and rough and completely main hole.

Rule № 70. If the machine 6 is busy, the work piece is fed to boring machines 7, which processes two ends and rough and completely main hole.

Rule № 80. If the boring machines 7 busy, the work piece is fed to horizontal milling machine 4, which processes two ends.

Rule № 90. If the machine 4 is busy, the process stop.

Rule № 100. The work piece is fed to the drilling machine 5 and if he is free and healthy, treated main hole roughly.

Rule № 110. If the machine 5 is busy, the process stop.

Rule № 120. The work piece is fed to a prolonged machine 8 and if he is free and working properly, then clean processing main hole.

Rule№ 130. If the machine 8 is busy, the process stop.

The following is the algorithm of IFMS, that can be programmed in any language (Delphi, C++ or PROLOG, LISP, etc).

For ease of analysis of functioning the IMS, the influence of environment is divided into two groups:

• Determined change given conditions of production (nomenclature, time of delivery, that is, calendar-production planning)

• random vibration conditions for the functioning - disturbances in the system such as cracks.

Then IMS is structurally divided into two generalized level, ordered according to the theory of intellectual machines: the organizational level, depending on the conditions of production and executive level, depending on the conditions of functioning manufacturing system.

4. Conclusions

1. It should be determined two areas of building intellectual manufacturing systems – first, top-down, by attaching a new component to an existing intellectual system, and, secondly, from the bottom up, by providing intellectual properties grassroots components, for example, as is typical for mechanic units.

2. Any production task, the algorithm of solution of which is unknown in advance or which is created on the basis of incomplete data, and systems, programs which perform the actions for the solution of this problem can be attributed to artificial intelligence, if the result of their work will be similar to the result of human activities in solving the same problem.

3. For technological systems the concept of artificial intelligence can be applied in their using of the subsystems, which change their algorithm operation depending on changes in external or internal conditions.

5. References

1. Gaines B.R., Norrie D.H. Knowledge Systematization in the International IMS Research Program // Proc. of IEEE Conference on Systems, Man and Cybernetics Intelligent Systems for 21st Century. -1995. - Vol.1. - P. 958 - 963.

2. Groover M.P., Zimmers E.W., CAD/CAM: computer-aided design and manufacturing. New Jersey: Prentice-Hall, 1984.

3. Opitz H., Wiendahl H.P., Group Technology and Manufacturing Systems for Medium Quantity Production, Intern. Journal of Prod. Res., 1971, vol. 9, no. 1, pp. 181-203.

4. Palchevsky B., Swic A., Krestianpol H., Computer integrated designing of flexible manufacturing systems, Lublin University of Technology, Lublin 2015.
5. Gola A., Świć A., Kramar V., A multiple-criteria approach to machine-tool selection for focused flexible manufacturing systems, Management & Production Engineering Review, 2011, vol. 2, no. 4, 21 – 32.
6. Waterman D. A Guide to Expert Systems: Translated from English .- M .: Mir, 1989.- 388 p.
7. Computer integrated planning, modelling end management / l.Yampolskyi, P.Melniczuk etc, .- Zhytomyr: ZhDTU, 2010.-786 p.