ГНУЧКІ ТЕХНОЛОГІЧНІ КОМПЛЕКСИ

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INFORNATION SOFTWARE FOR DESIGN OF FLEXIBLE MANUFACTURING SYSTEMS (FMS) OF PACKAGING

It is considered the information implementation for design of flexible manufacturing systems of packaging. It is showed the methods of synthesis of group process.

Flexible manufacturing systems of packaging, technological equipment, functional modules, flowsheet machine, layout

1. Introduction

The task of designing of FMS of packaging can be formulated as follows. The products of multiple items are packed on the FMS. The workplaces should provide a full range of packaging. Known drawings of packages, composition, volume and timing of release the packages, and directories with the characteristics of the equipment and technological equipment for the performing of operations, the sizes of the FMS section.

It is necessary:

- to determine the composition of the equipment,
- to distribute operations for workplaces,
- to determine the order of execution and the mode of operations..

The task should be solved so as to minimize the cost of all processes for given conditions.

Design of the FMS at this stage of their development is not possible without the active usage of information technology on the basis of a systematic approach.

2. Principles of Computer-Aided Design of the FMS of packaging

The flexible manufacturing system as a complex system should be considered in two aspects: functional and structural.

The functional aspect **sets the range of functions, that should be used by the FMS.**

The composition of the problems is defined by the result of functional design, that is solved by the technical means of FMS (ie, determine the functional structure of the workflow of the FMS).

The structural aspect provides the establishment of the composition of technical means of the FMS.

This is a structural or engineering design. Its realization provides a synthesis of the structure of the FMS, its analysis and optimization.

The FMS like any great technical system in engineering takes place several stages (Fig.1).

1. ***The first stage A1*** — determining of the destination of the FMS and its service poly-function, the development of technical specification (TS), i.e. the concretization of service poly-function of the FMS, the definition of its technical indicators.
2. ***The second stage A2*** — functional design of the FMS. Its main task — the development of the group process in engineering, suitable for the manufacture of a given product range, as well as the formation of group technological operations and their placement at the workplaces.
3. ***The third stage A3*** — designing of the structure (layout) of the FMS. Its main tasks — synthesis and structure optimization of the FMS.
4. ***The fourth stage A4*** — the concretization of constructive solution, which is defined by the structure of the FMS and set of component elements, the development of the working draft of the FMS.

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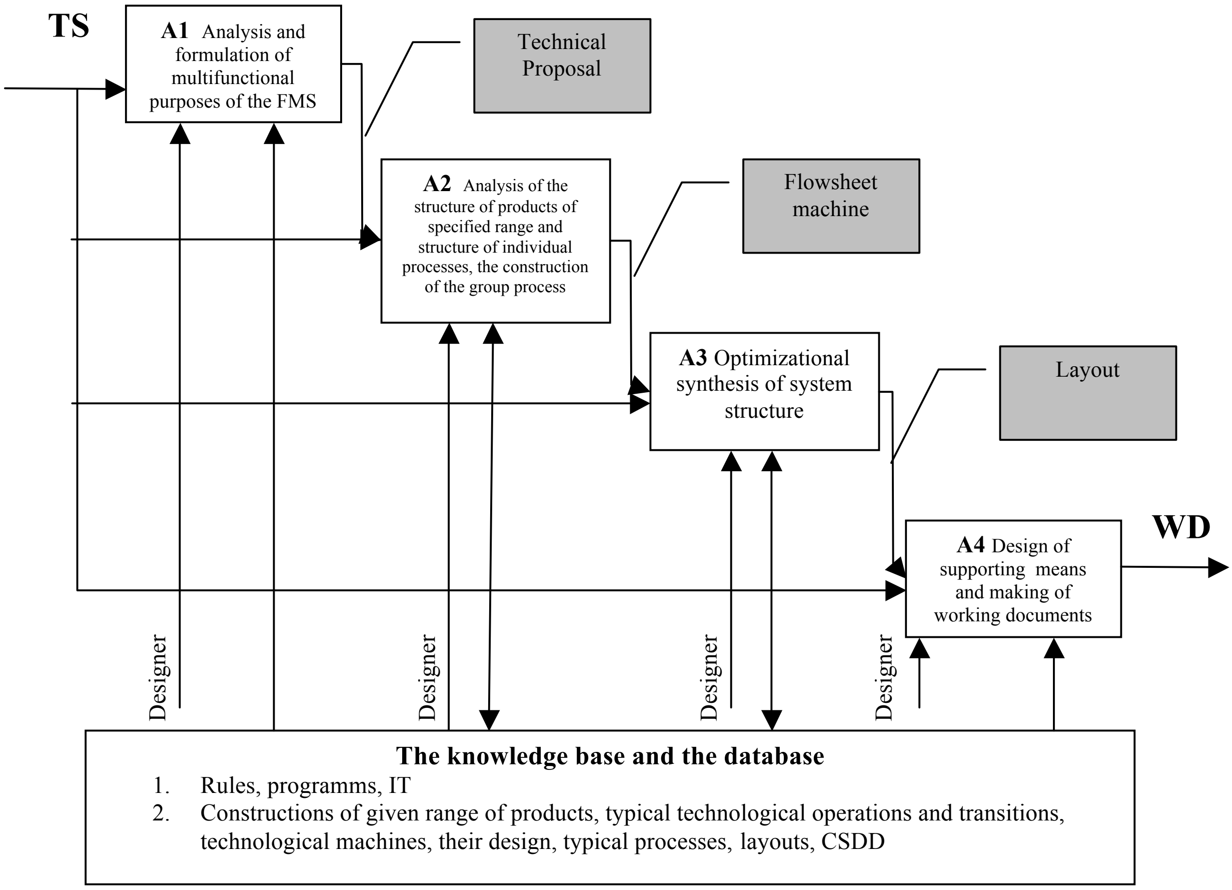

Fig. 1

3. Functional designing of Flexible Manufacturing Systems of packaging

3.1. A formal description of the technological and readjustable operations in the FMS

Functional designing allows to solve such problems:

- building of the structure of group technological process of the FMS;
- rational distribution of aggregate of functions, which are implemented in the FMS, between different workplaces;
- determination of the process structure of readjustment.

By an appointment we will divide the functions into three types: technological, supported and readjusted. We will assign to the technological functions that implement a given technological process and determine the technical control of the product, to the supporting – the functions of the displacement of products, their storage and accounting, diagnostics of the FMS, removal of waste products, etc., and to the readjustment – those that provide adaptation of the FMS to the packaging and production of other products or to the new working conditions.

The procedural model of group technological operation is given by a diagram (Fig.2) and by the vector:

$$TO = \{X, Y, Q, U\},$$

where ***X*** — input vector that consists of a plurality of parameters {xi}, i = 1, n;

Y — output vector that consists of a plurality of parameters {yj}; j = 1, m;

Q — technical means that are necessary for the implementation of technological operations;

U — control vector by the implementation of technological operation for a given Y;

S — control vector by the readjustments of technological operation.

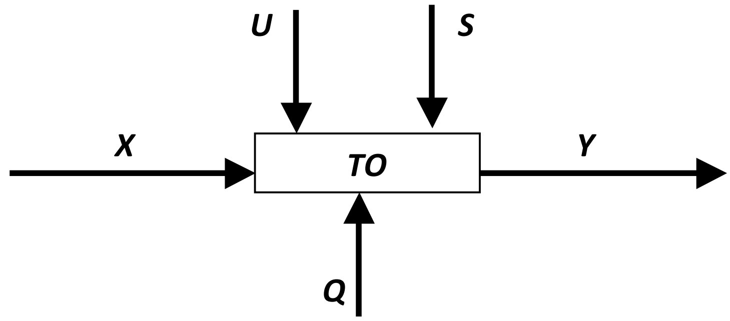

Fig. 2. The procedural model of group technological operation in the FMS

As can be seen from the procedural model of group technological operation within the FMS, such operation must be corresponded to not only the requirements of quality products, but also to the conditions of flexibility for adaptation (readjustment) for the manufacturing of products of given range with the specified productivity.

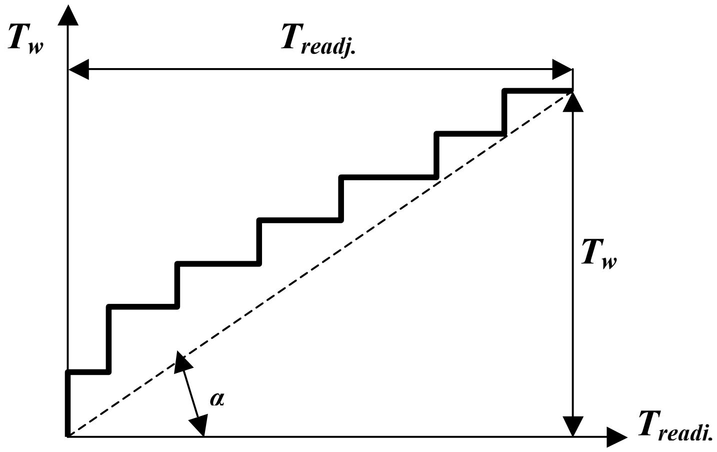

Fig. 3. Characteristics of the flexibility of technological operation in the FMS

The characterization of such flexible technological operation can be determined taking into account time cost in carrying out operations for the production of products and for the readjustment when the product changes (Fig. 3).

To describe the characteristics of the time cost on the adaptation of technological machines within the FMS to the manufacturing of a new product we will use the following factor:

$$tg\ \alpha = \frac{T_w}{T_{readj,i}} = \frac{\sum_i t_i \cdot P_i}{\sum_i T_{readj,i}},$$

where $T_{readj,i}$ – time of a readjustment of technological machine for the manufacturing of the i-th product, t_i – processing time of the i-th product, P_i – the magnitude of the party startup of the ith product.

The processes of readjustment are one of the main in the FAM, they have the same characteristics as the technological processes, that is, they have their own structure, they differ in the complexity and by the level of automation, they are characterized by a duration of realization etc.

The sources that lead to the readjustment of the FMS, as a rule can be:

1. **Designed -** changing in the designing of the product (shape, size, surface properties, physical and mechanical properties, structure etc.).
2. **Technological –** changing of the technological method, route, the structure of the operation, the change of control methods.
3. **Organizational -** changing of the methods of the transportation, accumulation, storage, program changing of issue or sequence of productivity of different products**.**

Suitability of the technological equipment to the readjustment in the implementation of group operations is characterized by their versatility.

The versatility of the FMS aims to increase the functions of technological machines for the expanding of the range of processed products. Since the modern packaging equipment is assembled from ready-made functional modules, so it is used a number of ways to increase versatility, modularity, taking into account their structure (Fig.4).

Ways of the increasing versatility can be divided into two large groups/features:

1. Increased versatility of the individual functional modules by:
   - Increasing the opportunities their regulation;
   - the dismemberment of the working parts with the following combinatorial usage of their parts Fig.5.
2. Increased versatility of the machine by changing its structure by:
   - the use of variables of functional modules;
   - the changing of the sequence of use of functional modules, that is, their permutation;
   - creating an excessive number of functional modules in the machine.

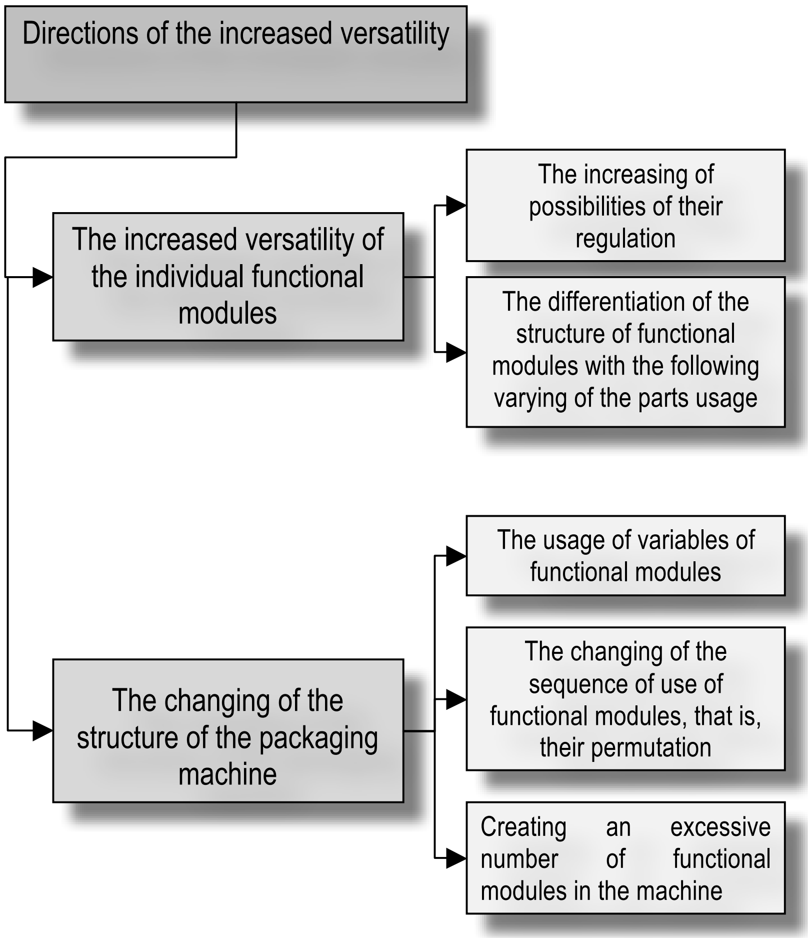

Fig.4. Directions of the increased versatility of technological machines

Using the changing working parts in the construction of a packaging machine is provided the possibility of replacing some working parts on the other with its readjustment to the production of other products. As an example can be an extension of the universal machine for the packing of granular products in the polymeric bags.

By the replacing of volumetric dispenser for the granular products on the volumetric piston dispenser is achieved the possibility of the using the same packaging machine for different kinds of products. The main disadvantage of this approach is the significant amount of time to dismantle some of the functional modules and to install them at the place of others.

The introduction of redundant functional modules in the design of the packaging machine. Only those working parts are included in the work, that are necessary for the production of a particular type, the rest working parts in the process of packaging of this type of product are not participated.

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As an example of this method is the automatic packaging machine of the company TAURAS-FENIX for viscous products, in which around the round table there are three dispensers – for the main product (yogurt), for additional (jam) and for the solid applications (nuts, chocolate powder). Depending on the structure of the packaged product, with the machine one, two or three dispensers are working.

The advantage of this method, compared to the previous one, there is practically no time cost on the readjustment. The transition to the production of other products by choosing another program in the control system in accordance with the characteristics of packaged products.

The main disadvantage of this method is the increasing in complexity, cost and size.
The maintenance of these machines is considerably more complicated.

Extension of the range of the regulation of working parts does not provide replacing the most working parts**.** An example of this approach is the piston dispenser for the viscous products. The possibility to doze different sized portions of the product is provided by changing the value of movement of the piston.

The separation of functional module for several elements with subsequent variation. For example, dispenser for packing pastes in polymer glasses is divided into four sections (Fig.5).

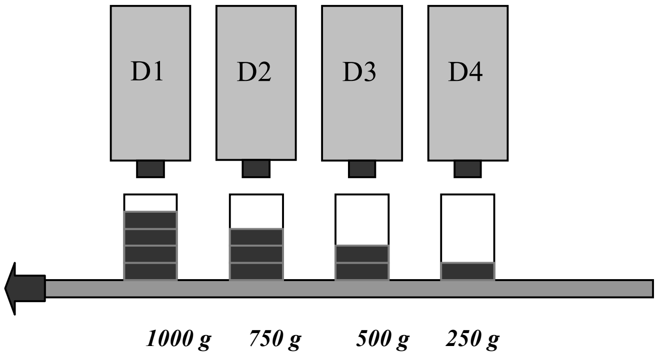


Fig. 5. Four-sectional dispenser

Each section of the working dispenser can be on or off. One section of the dispenser delivers 250 g. Depending on the task at packing, one, two, three or four sections of the dispenser are activated in different sequences, giving a single- or multicomponent dose of the product in 250, 500, 750 or 1000 g. Considering that the dose of product can be composed of different components and in a different sequence, it is also possible to modify the structure of the packaged product.

The order changing of the use of functional modules. The range of the FMS can be expanded by the order variation of operation of functional modules. For example, the order changing of filling of packaging by the various components of the product can be realized by the permutation of functional modules or by changing of the order of supplying the product to them.

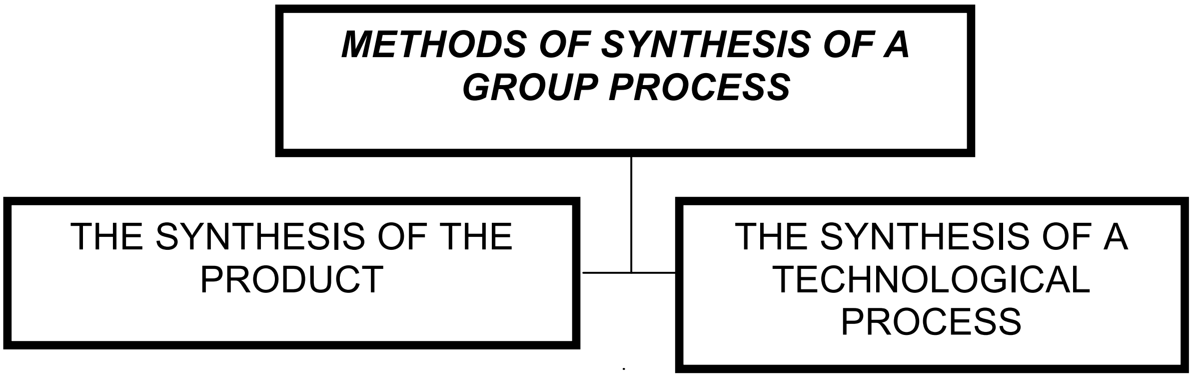
As you can see, the creation of the FMS is impossible without considering the interaction of technological processes and processes of readjustment. Since these processes are interrelated, so they form a common process, that is the basis for the optimization of the design of a machine system in the FMS.

3.2. The procedure for the synthesis of the group process of the FMS

The designing of a group process for packaging of products can be done in two ways:

1. **the technological synthesis of the group process**, which includes an analysis of individual processes for the specific products of specified range and a combining of single-type operations in the group, that are performed on the same equipment at a certain level of the readjustment;
2. **the synthesis of complex products**, which includes an analysis of structures of a given range of products, building of a virtual complex product, that includes all the elements of a given range of products, building of a group process with group operations for the manufacture of this virtual product and the virtual isolation of a generalized process of individual processes for each product of a specified range.

The procedure of the technological synthesis of the group process is a part of the project task of synthesis of the FMS with the optimal set of technologies. An identification of compatibility of technologies related to the operation of a specific FMS, which is in using for them the same equipment and tools, allows to reduce costs and to increase the coefficient of equipment utilization (Fig.6).



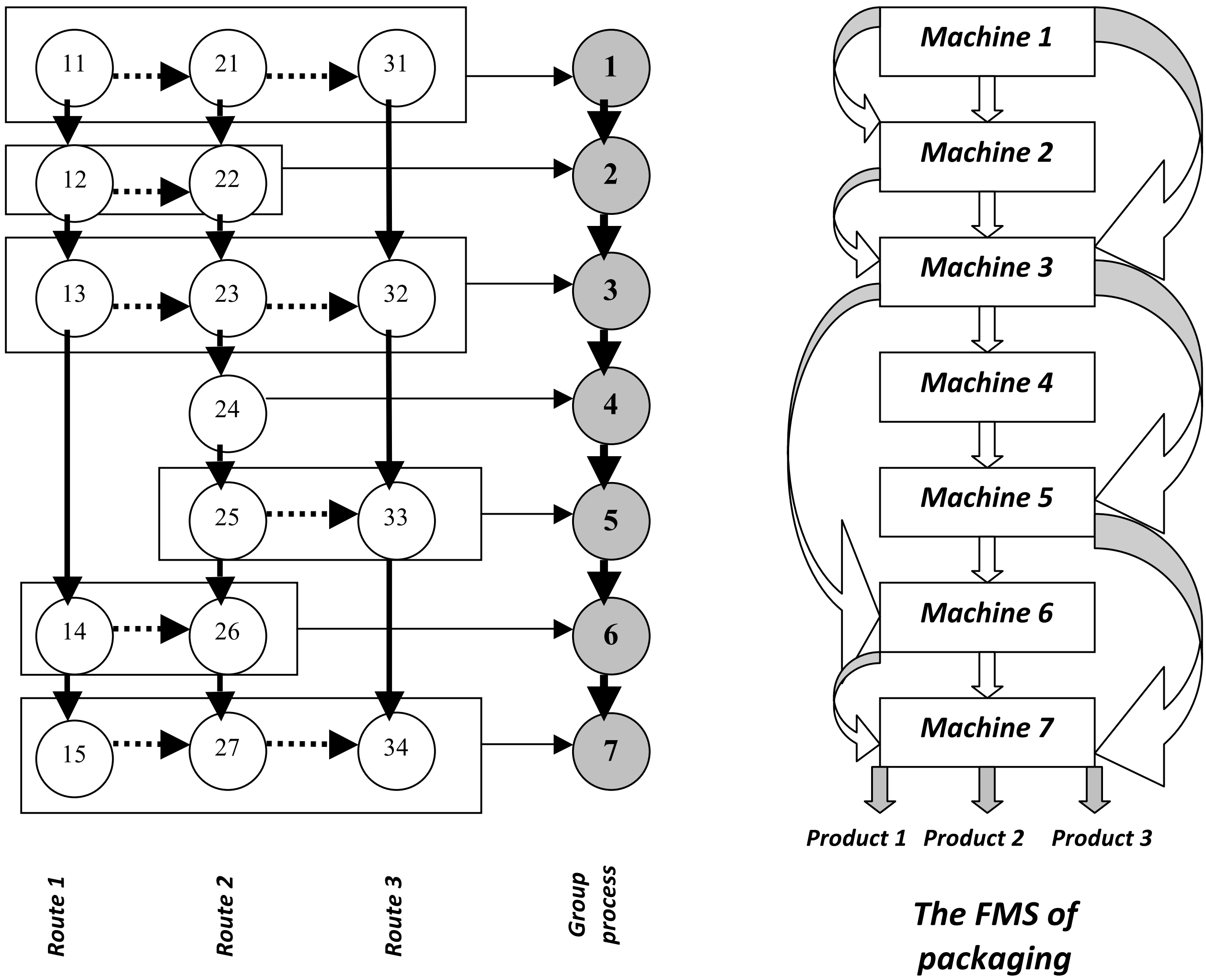


Fig.6 A group technological process

The analysis of the compatibility of technologies that are realized using the FMS, allows to determine the necessity of an attraction of additional technologies in a group process or expulsion of an active from the group process, but ineffective.

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For this it is necessary to calculate the ratio of the inclusion of technology in a group process as the ratio of the effect of E, that is provided by the technology, to the costs of its organization W

$$K_{IT} = \frac{E}{W}.$$

If this ratio is high for the technology, which is planned for the implementation in comparison with existing, it is necessary to make a decision about adding of a group process of the FMS.

To increase the flexibility of the FMS, it is necessary to predict the sequence of applications for a particular product, in accordance with this to prepare the individual routes for using. The probability of the use of technology can be assessed on the basis of available statistical data.

The procedure of synthesis of complex products. It is based on the grouping of products and the development of models based on the modular-element description of each product, the creation of this model of group technological process of packaging.

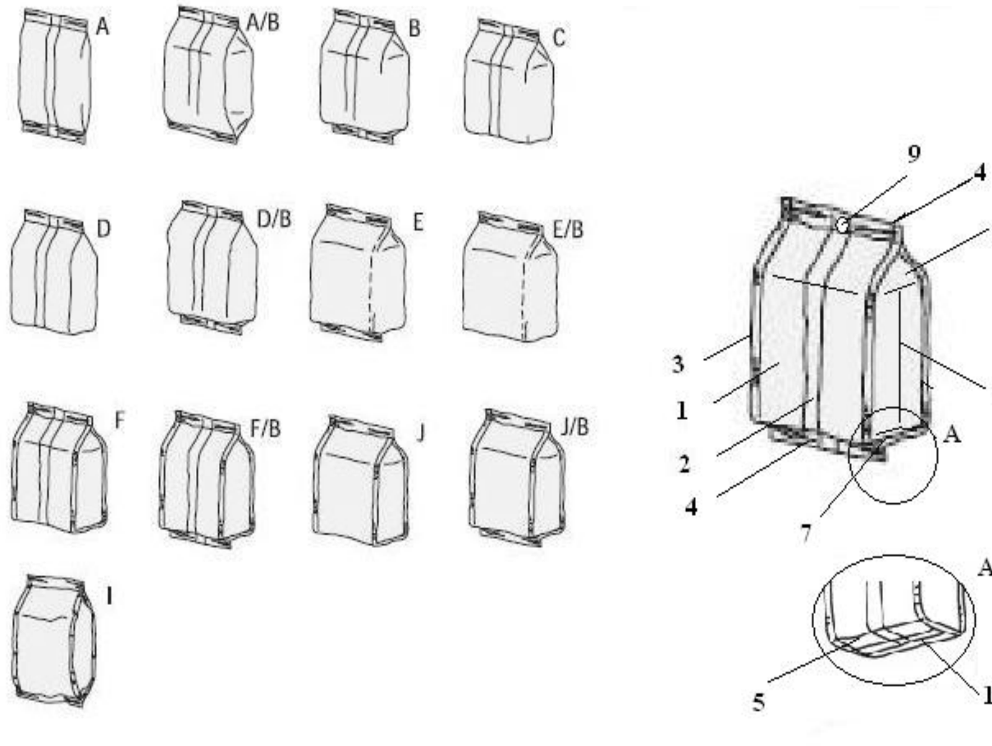

Fig. 7. Typical constructions of packages for granular products (a) and the elements of a complex package:

1 – casing, 2 – longitudinal seam, 3 – lateral commissure, 4 – transverse seams, 5 – bottom, 6 – the upper fold, 7 – the lower fold, 8 – lateral folds, 9 – the hole for hanging, 10 – curved lower fold

As an example, we will consider the use of such approach to the formation of a group technological process of packaging of granular materials. The most common consumer package of granular materials is a pack – a soft package with casing in the form of a sleeve, with the bottom of various configurations, with an open filler, with or without valves. The first step is defined by a set of constructive elements of the group of packaging (Fig.7,a). Each package of the group, according to the type, may have a set of certain constructive elements. A complex package (Fig. 7b)), on the basis of which is created a group process of manufacturing of packaging, contains elements that are common to all the above constructive types of packages. Accordingly, we will denote those elements a1, a2, ..., and a10. In addition, there are important the size of the package, from which depends on the width of plastic and the magnitude of dragging on a step when setting up the machine.

The systemic model of products is based on the basis of constructive elements of a complex package. It is believed that this model is set, the subsets of which are all real packages of group. As for the implementation of each constructive element of the package a_{ij}, you must perform a certain technological transition, so for the manufacture of the whole group of packaging, the FMS should have the technological capabilities for the implementation N of technological transitions

$$N = \sum_{i=1}^{n} \sum_{j=1}^{mi} a_{ij} \ ,$$

where a_{ij} – j-th element of the i-th package design,

n – number of constructive types of packaging in the group;

m_i – number of elements in the i-th packaging.

As in the real world on each of the technological machines can be implemented the multiple transitions, so the total number of transitions N , for which the FMS is created, can be significantly decreased. Moreover, the higher versatility of the equipment, the decrease is more substantial, the fewer pieces of equipment in the FMS and the structure is easier.

After the distinguishing of technology transitions or operations, the analysis of necessity of their implementation for each type of packages and a creation of a group technological process of packaging is carried out. On its basis the sequence of technological transitions or operations are taking, that are necessary to create a complex package.

4. Synthesis of the structure of the Flexible Manufacturing Systems of packaging

The layout of the FMS is produced by a set of technological equipment of different functions: machines for processing of packaging, dispensing of the product, connection of the product with the packaging, sealing, checkout, storage, transportation, washing and drying, etc. Each of these machines, depending on the complexity of operations, that is implemented, can have a different number of operating positions, various levels of versatility and automation, have different capacity and suitability for readjustment. Transport-accumulated subsystem includes in its structure the appropriate technical means for automatic loading and the transition of packaging, for an automatic removal of packages, and their accumulation etc.

Functional description of the FMS is the basis for the formation of the structure of the FMS.

The formation of many versions of the structure is possible creating of the layouts of the FMS due to the possibilities of using various types of technological equipment, different variants of distribution of operations at the workplaces and varying of other characteristics of the elements. Therefore the selection of the one from the available variants of structure of the FMS is very important. We will call it the solution of the problem of synthesis of the structure of the FMS.

It is necessary in the construction of the structure:

1. to distribute group operations over N products of a specified range, that are given by a set $B = \{b_1, b_2, ..., b_i, ..., b_N\}$ between M workplaces, that are given by a set received from a group technological process, i.e $WP = \{WP_1, WP_2, ..., WP_j, ..., WP_M\}$.

2. In addition, it is necessary for each workplace to choose from k_j possible that type of technological equipment that will provide higher efficiency of the FMS.

The structure of the FMS is also characterized by the number and by the different types of technological machines, that are installed at the workplace. Indeed, at each workplace the equipment can be set with different charecteristics (capacity, reliability, versatility, etc.) and with different values. This means that an optimization problem is occurred by choosing of the number and the type of technological machines for the realization of technological operations at the workplaces of the FMS.

At the j-th workplace of the FMS we can select the one from kj kinds of technical realization of the technological machine, that is,

$$Q_j = \{q_{j1}, q_{j2}, ..., q_{jk_j}, ..., q_{jm_j}\}.$$

Experience shows that the consideration of the specific problem of synthesis of the FMS greatly improves the efficiency of the computational procedure of the method "branch and bound".

Conclusions.

1.Design of the FMS is characterized by the active use of information technology on the basis of a systematic approach.

2.The main stages of computer-aided design are the formulation of the goals, an optimizational synthesis of a group process and layout of lines, and also the development of a virtual model of the line and its documentation.

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