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CHOICE OF OPTIMUM STRUCTURE AUTOMATIC PACKING MACHINE FOR PLASTIC FOOD PRODUCTS

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Abstract

Results of synthesis of structure of a packing machine for plastic food products and a choice of an optimum design of the functional module of dispensing are provided. For a choice of an optimum design of the dosing device the method of the criteria analysis is used and the complex of the criteria indexes describing process of relocation and dispensing of a product is developed. Results of researches can be used for a choice of optimum structure of package.

Keywords: *packing, plastic products, dispenser, criterion of optimization, analysis, index*

Introduction

At the present stage of development of the packing industry of the machine for packing plastic foodstuff acquires all-round application. It is caused by growth of the range of packed production, appearance of new packing materials and types of packages that in turn, causes in structural improved of packing machines for their adaptation to production requirements.

The Packing Machines (PM) of this type carry to multiposition technological machines of sequential action. Their structure is created on the basis of the modular principle, as method of creation of different technical systems with different characteristics by their configuration of standard modules definitely for creation of the material (transmission of products), energetic (the drive of mobile elements) and information (monitoring and control of operation) communications in between.

Each specific plastic product can be dosed different types of dispenser with use different constructive the diagram packing and automatic packing machines (APM) therefore as a result of their combination application of broad gamma of designs of APM is possible. Thus, from all existing diversity of APM intended for package of a specific plastic product it is necessary to reveal optimum option.

It is necessary to mark that optimization of a choice of APM can be executed in two stages:

- choice of the APM necessary type from a row of varied FPA;
- choice of optimum APM from a row similar to it in this type, selected at the first stage.

This optimization can be carried out by means of the criteria analysis [3].

Materials and Methods

The principle of operation of APM is based on interdependent movement of two material flows - a flow of packages of production and a flow of tare or a packing material. Package (preferentially soft) is made directly on APM.

If to provide process of packing in the form of a system graph with subsystems 1.1, 1.2, 2.1, 2.2, 3.1, 3.2 that in these researches explicitly we will analyze subsystems 2.2 and 2.1.

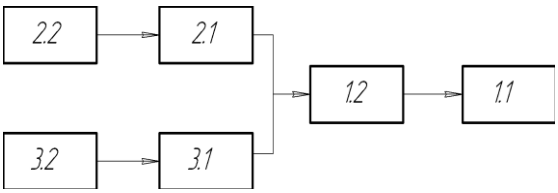

Figure 1. Process graph of packing of plastic production in soft package,

where 1.2, 1.1. - subsystems of preliminary and final manufacture of package;

2.2, 2.1 - subsystems of formation of a dose of a product and packing its (relocation) in package;

3.2, 3.1 - subsystems of completing of a packing material in the form of a roll and its submission on formation of package [2].

The theory of the criteria analysis and synthesis of processes considers so-called "perturbing factors" process, its shortcomings and errors to which it is possible to refer knock, vibration, shocks, pushes, a pulsation, complexity of the process sometimes realized on difficult space trajectories of centers of masses of objects of processing, violation of a trade dress of products and many other things. These factors can be classified and implemented functionally in the form of special criteria of synthesis and corresponding to

them "criteria indexes". Namely:

1) m – the index characterizing friction of a product on working organs of the dispenser:

$$m = \sum m_j, \quad (1)$$

$$m_o = 0 \quad if \quad \sum m_j = 0, \quad (2)$$

where m_0 - best numerical value of this criteria index.

2) f – characterizes the turbulences arising in the course of relocation of a product in the dispenser (elements of paths with sharp changes of their direction at any angle are considered):

$$f = \sum f_j, \quad (3)$$

$$f_o = 0 \quad if \quad \sum f_i = 0, \quad (4)$$

where f_o - best numerical value this criteria an index. In case of f_o=0 turbulences are absent.

3) r - characterizes a continuity or recurrence of all process of packing (a subsystem 1.1, 1.2, 2.1, 2.2, 3.1, 3.2) that corresponds to a machine cycle, and considers t_x no-load time since all time of a cycle of the machine:

$$r = t_x \ (c^{-1}), \quad (5)$$

$$r_o = 0 \quad if \quad t_x = 0, \quad (6)$$

where r_o - best numerical value of this criteria index. In case of r_o = 0 there is no recurrence of process, i.e. process is the continuous.

4) n - considers number of technological operations as the executed device of submission

$$n = \sum n_j - n_{min}, \quad (7)$$

where n_j - the current value of executed technological operations;

n_{min} - minimum possible number of executed technological operations.

$$n_o = 0 \quad if \quad n_j = n_{min}, \quad (8)$$

where n_o - best numerical value of this criteria index. It is the optimum process executed with minimum possible number of technological operations, and consequently, reliable and economically expedient.

5) v – the index characterizing traverse speed of a product in package (scanning in a matrix):

$$v = \sum v_j, \quad (9)$$

$$v_o = 0 \quad if \quad \sum v_j = 0, \quad (10)$$

6) ∂ – the index characterizing change of pressure in the dispenser in case of movement of a working organ:

$$\ddot{a} = \sum \ddot{a}_j, \quad (11)$$

$$\partial_0 = 0 \ \ if \ \ \sum \partial_o = 0, \quad (12)$$

All found out functionally different "perturbing factors" process - value the dimensionless that allowed not only to consider scrupulously them, but also to add.

In these researches coefficients of ponderability of fi which are defined by the ad hoc method of ranging which was developed by prof. Panishev V. G. [1] also were used. With their help it is received the weighed amounts of numerical values of the criteria indexes, necessary in case of a choice of optimum process of dispensing. Values of coefficients of ponderability are tabulated.

Table 1. Numerical values of coefficients of ponderability f_j and appropriate indexes j

∂	r	n	v	m	f
f_∂	f_r	f_n	f_v	f_m	f_f
0,15	0,21	0,07	0,28	0,26	0,19

For execution of the criteria analysis by a researched product it was chosen cottage cheese mass (the main rheological characteristics of a product: volume mass - 1060 kg/m^3; plastic viscosity - 15 Pa*s; ultimate stress of shift - 93,4 Pa) [4].

As the necessary and sufficient choice was accepted by at least three options of processes of dispensing of cottage cheese mass based on the provided characteristics of a product:

- the machine with the volume feed-screw-piston dispenser without crane accessories of rotor type;
- the machine with the volume feed-screw-piston dispenser with crane shutoff valves;
- the machine with the volume gear dispenser.

On each process which is executed above given by machines, it was probed formation process (2.2.) and relocation (2.1) doses of a product, are constructed the diagrams, appropriate tables and diagrams, decryptions of criteria indexes are carried out.

1. The volume feed-screw-piston dispenser without shutoff valves of rotor type (П1).

The diagram of process is given in a figure 2. Such diagram demonstrates a process course. On a course of process we put down criteria indexes j, and we provide the generalized table with their numerical values and weight factors below.

Decryption of criteria indexes of process of formation of a dose, subsystem 2.2.

Index «*m*»:

m_1 – friction of production in the course of its submission in the bunker (on the screw and bunker walls);

m_2 – friction of production on the submission channel to a measured sleeve;

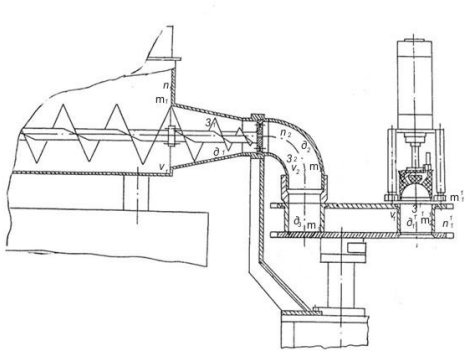

Figure 2. Diagram of the volume feed-screw-piston dispenser without shutoff valves of rotor type for formation of a dose and package of cottage cheese mass.

m_2 – friction of production on the submission channel to a measured sleeve;

m_3 – friction of production in a measured sleeve on walls.

Index «*r*»:

П - piece productivity on one flow, accepted from the reference.

Index «*n*»:

n_1 – operation of submission of a product in the bunker;

n_2 – operation of relocation of a product along the bunker by means of the feed-screw;

n_3 operation of relocation of a product in a measured sleeve.

Index «*f*»:

f_1 – formation of turbulences in case of production submission in the bunker (in case of feed-screw movement);

f_2 – formation of turbulences in case of production relocation on the channel in measured sleeves.

Index «*v*»:

v_1 - production forcing in the bunker with constant speed;

v_2 – production relocation on the channel in measured sleeves with constant speed.

Index «*∂*»:

$\partial 1$ – pressure arising in case of forcing of a product by means of the feed-screw;

∂_2 – pressure arising in case of relocation of production on the channel;

∂_3 - pressure arising in a measured sleeve.

Decryption of criteria indexes of process of formation of a dose, subsystem 2.1.

Index «*m*»:

m_1 – friction of production in a sleeve on a piston wall;

m_2 – friction of production on a wall of a measured sleeve.

Index «*r*»:

Cycles 2.1 and 2.2 belong to one process 2, and therefore here we accept value of an index equal 2.2.

Index «*n*»:

n_1 – operation of relocation of a product on a dispenser sleeve by means of the piston.

Index «f»:

f_1 – formations of turbulences of a product in a sleeve in case of piston movement (production extrusion).

Index «v»:

v_1 – product extrusions by the piston in a measured sleeve with constant speed.

Index «∂ »:

∂_1 – pressure arising in case of extrusion of production by the piston.

Table 2. Numerical values of indexes j and weight factors f_i for the volume feed-screw-piston dispenser without crane accessories of rotor type

	∂	***v***	***m***	***f***	***r***	***n***	$\sum j$
s/s 2.2	3	2	3	2	0,225	3	13,225
s/s 2.1	1	1	2	1	0,225	1	6,225
$\sum s/s$ **2.1, 2.2**	4	3	5	3	0,225	4	22,225
$\mathbf{f_j}$	0,15	0,28	0,26	0,19	0,21	0,07	

2 . The volume feed-screw-piston dispenser with crane shutoff valves (П2).

After creation of the diagram of process of formation and transmission of a dose of a product criteria indexes j are put down, and the table with their numerical values and weight factors was created.

Decryption of criteria indexes of process of formation of a dose, subsystem 2.2.

Index «*m*»:

m_1 - friction of production in the course of its submission in the bunker (on the feed-screw and to bunker walls);

m_2 - friction of production on the submission channel in the measured cylinder;

m_3 - friction of production in the measured cylinder on walls;

m_4 - friction of production in the measured cylinder on piston walls.

Index «*r*»:

П - piece productivity on one flow, accepted from the reference.

Index «*n*»:

n_1 - operation of submission of a product in the bunker;

n_2 - operation of relocation of a product along the bunker;

n_3 - operation of relocation of a product in the dosing cylinder.

Index «*f*»:

f_1 – formations of turbulences in case of production submission in the bunker (in case of feed-screw movement);

f_2 – formation of turbulences in case of production relocation in a measured sleeve.

Index «*v*»

v_1 – production forcing in the bunker at constant angular velocity of the feed-screw;

v_2 – production relocation in a measured sleeve with constant speed.

Index «*∂*»:

*∂*1 – pressure arising in case of forcing of a product by means of the feed-screw;

∂_2 – pressure arising in case of relocation of production on the channel;

∂_3 - pressure arising in a measured sleeve.

Decryption of criteria indexes of process of formation of a dose, subsystem 2.1.

Index «*m*»:

m_1 - friction of production in the measured cylinder on piston walls;

m_2 - friction of production on walls of the measured cylinder in case of piston movement;

m_3 - friction of production in crane shutoff valves;

m_4 - friction of production in splitters.

Index «*r*»:

Cycles 2.1 and 2.2. belong to one process 2, and therefore here we accept value of an index equal 2.2.

Index «*n*»:

n_1 - operation of relocation of a product on dosing the cylinder in case of extrusion of a portion by the piston;

n_2 - operation of relocation of a dose in crane shutoff valves;

n_3 - operation of relocation of a dose on a branch pipe of the easel (splitter).

Index «*f*»:

f_1 – formation of turbulences in the dosing cylinder in case of piston movement (dose extrusion);

f_2 – formation of turbulences in case of production relocation in crane accessories;

f_3 – formation of turbulences in case of production relocation on an easel branch pipe.

Index «*v*»:

v_1 – production extrusion by the piston with constant speed;

v_2 – production relocation to crane accessories with greater speed;

v_3 – production relocation on an easel branch pipe.

Index «*∂*»:

*∂*1 – pressure arising in case of extrusion of a dose of production by the piston;

∂_2 – pressure arising in case of relocation of production to crane accessories;

∂_3 - pressure arising in case of relocation of production on a crane branch pipe.

Table 3. Numerical values of indexes j and coefficients of ponderability f_i for the volume feed-screw -piston dispenser with crane shutoff valves

	∂	*v*	*m*	*f*	*r*	*n*	$\sum j$
s/s 2.2	3	2	4	2	0,276	3	14,276
s/s 2.1	3	3	4	3	0,276	3	16,276
$\sum s/s$ **2.1, 2.2**	6	5	8	5	0,276	6	30,276
$\mathbf{f_j}$	0,15	0,28	0,26	0,19	0,21	0,07	

3. Volume gear dispenser (П3).

After creation of the diagram of process of formation and transmission of a dose of a product criteria indexes j are put down, and the table with their numerical values and weight factors was created.

Decryption of criteria indexes of process of formation of a dose, subsystem 2.2.

Index «*m*»:

m_1 - friction of production in the bunker in case of submission in the camera with gearwheels;

m_2 - friction of production on camera walls;

m_3 - friction of production on gearwheels;

m_4 - friction of production on channel walls.

Index «*r*»:

П - piece productivity on one flow, accepted from the reference.

Index «*n*»:

n_1 - operation of submission and product relocation in the bunker;

n_2 - operation of relocation of a product in the camera with gearwheels;

n_3 - operation of relocation of a product from the camera to the channel.

Index «*f*»:

f_1 – formation of turbulences in the dosing cylinder in case of product submission from the bunker in the camera with gearwheels;

f_2 – formation of turbulences in case of production relocation in the camera with gearwheels;

f_3 – formation of turbulences in case of production relocation on the final channel.

Index «*v*»:

v_1 – feed speed of a product from the bunker in the camera with gearwheels;

v_2 – traverse speed of production in case of movement of gearwheels in the camera;

v_3 – constant speed of relocation of a product on the final channel.

Index «*∂*»:

$\partial 1$ – pressure arising in case of submission of a product from the bunker in the camera with gearwheels;

∂_2 – pressure arising in case of relocation of production in the camera with gearwheels;

∂_3 - pressure arising in case of relocation of production on the channel.

Decryption of criteria indexes of process of formation of a dose, subsystem 2.1.

Index «*m*»:

m_1 - friction of production on walls of the final channel before valve turn;

m_2 - friction of production on walls of the channel of return of a dose;

m_3 - friction of production on valve walls;

m_4 - friction of production on walls of the final channel after valve turn.

Index «*r*»:

Cycles 2.1 and 2.2. belong to one process 2, and therefore here we accept value of an index equal 2.2.

Index «*n*»:

n_1 - transaction of relocation of a product of the channel of return of a dose;

n_2 - operation of relocation of a dose after valve turn.

Index «*f*»:

f_1 – formation of turbulences in the final channel before valve turn;

f_2 – formation of turbulences in case of production relocation in the channel of return of production;

f_3 – formation of turbulences of production after valve resetting.

Index «*v*»:

v_1 – motion speed of a product on the final channel before valve turn;

v_2 – traverse speed of production in the channel of return of a dose;

v_3 – traverse speed of a product on the final channel after valve turn.

Index «*∂*»:

$\partial 1$ – pressure arising in the channel before turn of the valve;

∂_2 – pressure arising in the channel of return of a dose;

∂_3 - pressure arising in case of relocation of production on the channel on resetting of the valve.

Table 4. The generalized table of numerical values of indexes j and weight factors of f_i for volume gear dispenser

	∂	***v***	***m***	***f***	***r***	***n***	$\sum j$
s/s 2.2	3	3	4	3	0,2	3	16,2
s/s 2.1	3	3	4	3	0,2	2	15,2
$\sum$ **s/s 2.1, 2.2**	6	6	8	6	0,2	5	29,2
$\mathbf{f_j}$	0,15	0,28	0,26	0,19	0,21	0,07	

Results, Discussion

The analysis of processes at the choice of optimum process of dispensing was carried out by means of diagrams of summary and differentiated numerical values of criteria indexes of processes. However the final choice of optimum option of process should be realized on the generalized the table which is called as a matrix of decisions.

The diagram of summary numerical values of criteria indexes of all three selected processes of dispensing and packing is given in a figure 3.

From the chart it is visible that each column is the amount of errors of process, it "perturbing factors" (turbulences) expressed by the dimensionless numerical values index. It is quite natural that the smallest column and will reflect best of researched processes. According to graphic representation by the optimum it is necessary to consider the process of П1 executed by the volume feed-screw dispenser.

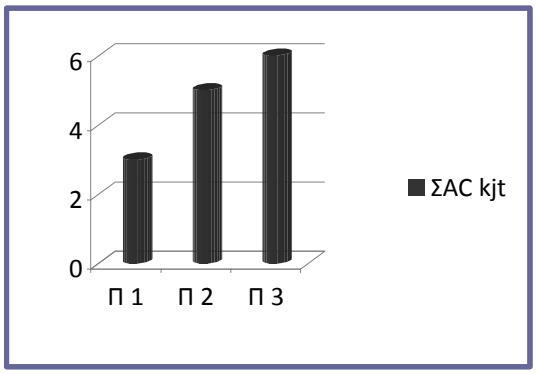

Figure 3. Chart of summary numerical values of the indexes for П1, П2, П3.

In cases when a vector of two or several processes match, or are very close, for detection of best of them use diagrams of differentiated numerical values of indexes (fig. 4). The best will be that process which has smaller numerical value at least on one of indexes.

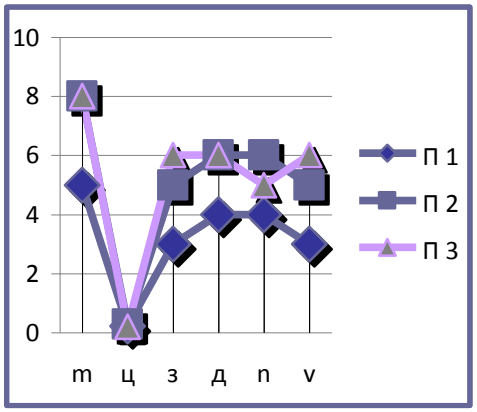

Figure 4. General diagram of differentiated numerical values of indexes П1, П2, П3.

In the conducted researches П3 and П2 processes are closest, however on a difference of indexes process of П1 executed by volume feed-screw-piston by the dispenser without crane accessories of rotor type will be the best.

By results of the executed researches it was constructed a matrix of decisions (table 5). In the upper part of lines process is characterized by numerical values of separate criteria indexes and their amount, and in the lower part - the weighed values. Therefore more quickly and visually it is possible to receive the characteristic of any process by simple summing of numerical values of indexes in top line. Their minimum amount will be optimum option of process.

Table 5. Matrix of decisions

Пj	*Am* *fm*	*Aд* *fд*	*Ar* *Ar*	*An* *fn*	*Av* *fv*	A_f f_f	*Σ* *Aij·fj*
П1	5	4	0,225	4	3	3	22,225
	1,3	0,6	0,047	0,28	0,025	0,57	2,822
П2	8	6	0,276	6	5	5	30,276
	2,08	0,9	0,057	0,42	1,4	0,95	4,807
П3	8	6	0,2	5	6	6	29,2
	2,08	0,9	0,042	0,35	1,68	1,14	6,192

Conclusion

Use of a technique of a choice of optimum structure of APM for plastic foodstuff on the basis of the criteria analysis allows is reasoned to select best of constructive options of executions of the module of dispensing.

Use offered the technique will allow to evaluate and select further more effectively optimum option of APM for plastic foodstuff from a row of the similar.

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