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INFORMATION MODEL OF PLASTIC PRODUCTS FORMATION PROCESS DURATION BY INJECTION MOLDING METHOD

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ABSTRACT

Plastic products formation process duration is the important parameter of technological injection molding. For information combination on several parameters of plastic products formation the Venn diagram has been used. The diagram contains the whole set of possible parameters (sample space). Having chosen rational parameters for optimum duration achievement of formation process, it is offered to formalize them by means of information model. On the basis of the Venn diagram, an information model is proposed for the duration of the plastic products molding process by injection molding. The information model can be the basis for a mathematical model that will enable the development of a module for molding process automated control. The information model of the molding process duration reflects the parameters of the process and the service features of the injection mold.

Keywords: Information, Model, Plastic, a Cycle, Injection Molding.

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1. INTRODUCTION

Consumption of plastic products (PP) is growing with everyone. The fleet of injection molding machines (IMM) and the range of plastics are developing successfully. The main reason for their wide distribution is: a relatively low price; ease of processing; properties – a wide range of physical and mechanical properties [1, 2].

More than a third of the total plastic products volume is produced by injection molding (IM) [1, 3]. Production lines for the PP production are inexpensive, within the shortest time you can change the range of their products. Therefore, the formation of a PP is a relevant and in demand line of modern scientific research [4, 5]. At PP formation continuous structurization and optimization of data and also possibilities of their use is necessary. At the same time the information model (IM) is a key. Such a model is presented in an information type that describes parameters and variables, essential to a concrete case, communications between them and also entrances and exits for data on which when giving it is possible to influence the received result.

Plastic products formation process duration (FPD) – one of the most important parameters of the injection molding technological process [5, 6]. FPD plastic products have a great impact on the cost and performance characteristics of molded products made of thermoplastic materials. Thus, the construction of an adequate information model is an urgent task.

2. MATERIALS AND METHODS

2.1. Related work

Numerous studies have been devoted to the study of the plastic molding process by injection molding [1, 5-9].

In work [1] the concept of plastic injection molding duration is described. Based on work [1] it is possible to define a plastic formation algorithm for casting duration optimum achievement. In [5] the comprehensive current state review of the hot-runner molds application which is the most widespread for today is presented. The principles of such molds development and their applied examples realization are considered. Bases definitions of formation process duration are given. Based on work [6] it is possible to define the main aspects at information space creation.

In [7] examples of information models development are given. Information modeling features of subject domain are considered. On the basis of [8] fundamental concepts of information models are defined and presented verbal and sign; mathematical and computer IM. Based on work [9] it is possible to define methodology of information modeling; requirements when modeling separate products and processes.

Thus, it can be seen that numerous recommendations have been developed on the correct molding parameters choice to ensure the release of products with high performance properties. However, the influence of the molding process duration parameters on the fabrication quality has not been sufficiently studied and is not sufficiently formalized. At the same time, taking into account the existing fluctuations in the parameters of the molding process duration, the quality control of finished products acquires has no small importance.

2.2. Model proposed

The aim of the work is to develop an information model of plastic products formation process duration by injection molding. Automated control system (ACS), of the formation process duration, as well as other automated systems, is associated with permanent or basic information that characterizes objects, information about which can be used in the management process. These data are the information basis for the automated process control and constitute the information support of the automatic control system by the formation process. First of all, it seems necessary to analyze the mechanism of forming an information model for the molding process duration. This will improve the efficiency of developing algorithms in the automated control processes.

By the molding process duration, we mean the injection molding cycle of a plastic product, FPD plastic products include time to perform [1, 5-12]:

1. Mold closure. Closure of the mold occurs before filling it with the material (this time – τ_{clo}). It can be determined by the accelerated and retarded movement of the movable IMM plate and the movement of the movable plate mold. It depends on the PP design and the mold. The definition τ_{clo} does not depend on the nests number [1, 10].

2. Approach and squeeze the injection unit to the sprue bushing. Movement of the plastication unit forward with the mouthpiece pressed against the sprue bushing of the mold. At hot runner system the plastication knot remains pressed to mold throughout all formation process [10].

3. Injection of the plasticized weight in a mold. Having FPD analyzed it is defined that the significant effect on injection plays nests quantity in mold [12]. The general duration of injection in all gates, depends on their quantity and is for average machines of 1.5-2 sec. However, the share of injection time falling on one gate $\tau_{spr} - 1$ as size extremely small can be neglected [10]. Value τ_{spr} can be approximate and depends on the injection volume [1, 11]: 1 sec – for v_o to 63 cm^3; 2 sec – for v_o to 150 cm^3; 3 sec – for v_o to 400 cm^3; 4 sec – for v_o to 1000 cm^3.

4. Hold under pressure. The simplest and most reliable way to determine the required holding time under pressure is to consistently weigh the casting [10, 11]. At constant IM conditions, with the exception of the holding time under pressure, which changes by 1 to 2 seconds depending on the required accuracy, several PP are successively cast. Extremely small value in molds for non-gates injection molding is the share τ_{hup} falling on one gate $\tau_{hup} n^{-1}$. At increase in diameter or PP duration the number of inlets increases. The minimum time is considered optimal τ_{hup} after which PP weight doesn't increase any more.

5. Mold cures or PP cooling process. It is hold when cooling (τ_{cool}) [11]. The cure time or cooling's in mold depends from: temperature at which the product of this design can be it is taken has to exclude danger of its damage from a matrix reliably; the maximal matrix temperature at the time of the beginning mold opening, (it is higher than punch temperature); melt temperatures at the time of receipt to the molding cavity; heat conductivity; specific heat; density; wall PP thickness; heat diffusivities [11, 12].

6. ***Withdrawal of an injection unit.*** Withdrawal of an injection unit (nozzle) is carried out when using mold with the stiffening gate for decrease of a heat transfer from a hot mouthpiece to a cold sprue bush.

7. Mold opening and a finished product expulsion in the tray attached to the bed. Mold opening happens after the end of cooling operation. The moving mold part goes with the product, at the same time the sprue of cold-channels mold is taken from a sprue bush [11].

The sequence of the operations discussed above depends on the operating mode of the injection molding machine, which, on the whole, determines the duration of the plastic product molding process. Peculiarities of the PP molding process duration can be revealed by system – structural analysis, which shows how the parameters and information about these parameters are combined into sets. As a form of information expression, the Venn diagram is chosen, one of the types of graphic organizers, which allows analysis and synthesis to be performed when two or more objects (phenomena, facts, concepts) are considered [7, 8]. Fig. 1 shows the Venn diagram, which illustrates the relationship between the FPD structural units. The diagram has a pronounced hierarchical character. The number of dissection levels for different units of the diagram is different, which emphasizes the complexity of constructing the corresponding IM.

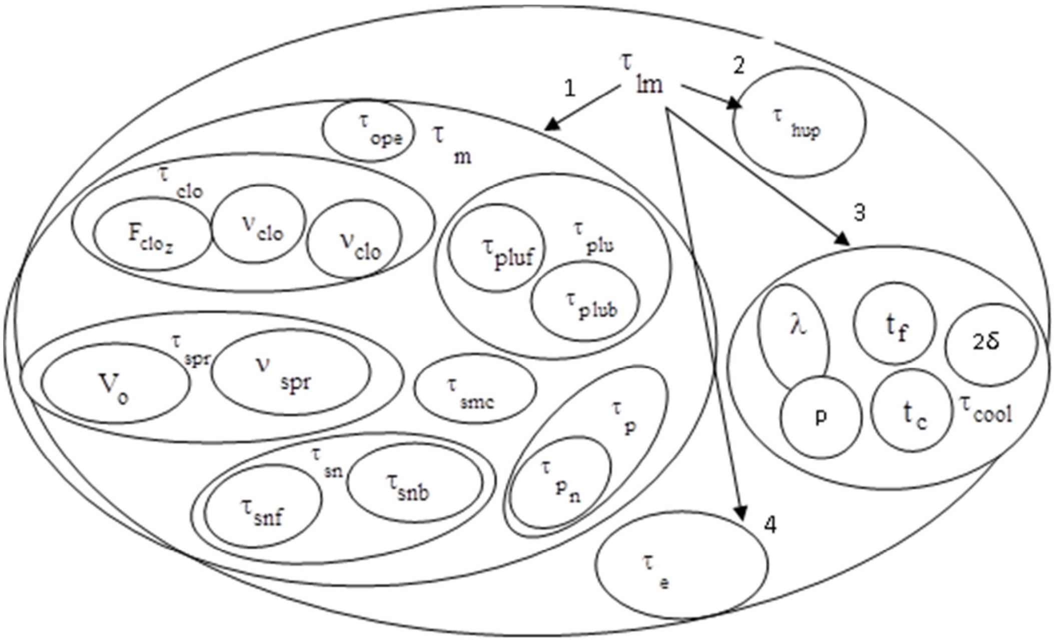

Figure 1 The generalized Venn diagram of the relations between base FPD units

The molding process duration of the plastic products τ_{lm} generally includes four structural units (see Fig. 1). Let there are many options for the molding plastic products process duration, which will consist of subsets

$$\tau_{lm} = < \tau_{m_i^j}, \tau_{hup_i^j}, \tau_{cool_i^j}, \tau_{e_i^j} >, \qquad (1)$$

where $\tau_{m_i^j}$ – machine time; $\tau_{hup_i^j}$ – hold time under pressure; $\tau_{cool_i^j}$ – time of a mold cooling; $\tau_{e_i^j}$ – extraction time of a product from a matrix; i – number of formation process, $i = 1,..., I$; j – type of the formed plastic product $j = 1,..., J$.

The first subset of the information model (1) – machine time is represented as:

$$\tau_{m_i^j} = < \tau_{clo_i^j}, \tau_{spr_i^j}, \tau_{ope_i^j}, \tau_{p_i^j}, \tau_{sn_i^j}, \tau_{plu_i^j}, \tau_{smc_i^j} >, \qquad (2)$$

where $\tau_{clo_i^j}$ – time closing the mold; $\tau_{spr_i^j}$ – injection time of a plastic material melt in an mold; $\tau_{ope_i^j}$ – time opening the mold; $\tau_{p_i^j}$ – pause time (mold service); $\tau_{sn_i^j}$ – "course" time of a nozzle (supply); $\tau_{plu_i^j}$ – "course" time of a plunger / screw; $\tau_{smc_i^j}$ – estimated time of melt stay in the cylinder; i – number of formation process, $i = 1,..., I$; j – type of the formed plastic product $j = 1,..., J$.

We consider each element of the subset (2). We will describe time closing the mold as:

$$\tau_{clo_i^j} = < F_{clo_z}, \nu_{clo}, r_{clo} >, \tag{3}$$

where F_{clo_z} – effort of closing the mold, that is, the sum of efforts with which columns are loaded on stretching at a mold clamp before injection; ν_{clo} – speed of closing the mold; r_{clo} – distance between the moving plate of IMM and the moving mold plate.

The effort of closing the mold can be expressed through:

$$F_{clo_z} = < F_{clo}^{IMM}, P_{mp}, S_{pp}, N >, \tag{4}$$

where F_{clo}^{IMM} – effort of IMM locking; P_{mp} – specific pressure of a melt in mold (reference data for each concrete material); S_{pp} – area of a product projection (that is, a product projection to the plane concerning which closing-opening of mold will be carried out); N – number of mold gates.

Injection time of a plastic material melt in an injection mold contains such parameters:

$$\tau_{spr_i^j} = < V_o, \nu_{spr} >, \tag{5}$$

where V_o – estimated volume of the casting products with the sprues; ν_{spr} – injection rate of a melt in mold.

Let the estimated volume of the casting products with the sprues are determined as:

$$V_o = < V_{md}^k, V_{mc}^k >, \tag{6}$$

where V_{md}^k – mold piece volume at k – number of mold pieces in mold $k = 1,..., K$; V_{mc}^k – volume of inlet sprue channels at k – quantity of inlet sprue channels $k = 1,..., K$.

Time of opening the mold consists from:

$$\tau_{ope_i^j} = < F_{ope_r}, \nu_{ope}, r_{ope} >, \tag{7}$$

where F_{ope_r} – effort of opening the mold; ν_{ope} – speed of opening the mold; r_{ope} – distance between the moving IMM plate and the moving mold plate (distance of opening the mold) [1, 10].

Due to the variety of PP designs and casting conditions, mold service life cannot be guaranteed. Maintenance of the mold is not the responsibility of the manufacturer. At the same time, when formalizing the pause time, cases are not taken into account when maintenance is necessary due to wear caused by abrasive material, improper form maintenance or the use of inappropriate technology.

Then the pause time (servicing of the injection mold) should include such parameters:

$$\tau_{p\,j_i} =< \tau_c^{y_i}, \tau_o^{y_i}, \tau_{cl}^{y_i}, \tau_{co}^{y_i}, \tau_{ad}^{y_i}, \tau_{la}^{y_i}, \tau_r^{y_i} >, \quad (8)$$

where $\tau_c^{y_i}$ – time for replacement of the broken easily replaced mold details at y – type of the broken detail (for example, a spring, the pusher) $y = 1,..., Y$; i – quantity of the broken details y-th type $i = 1,..., I$; $\tau_o^{y_i}$ – time for replacement of the fast-worn-out mold details at y – type of a worn-out detail (for example, laying) $y = 1,..., Y$; i – quantity of worn-out details y-th type $i = 1,..., I$; $\tau_{cl}^{y_i}$ – time for a clearing of the mold elements (for example, an opening clearing from a flash) at y – element type; i – quantity of the elements y-th type, $i = 1,..., I$; $\tau_{co}^{y_i}$ – time for covering of the mold elements at y – element type; i – quantity of the elements y-th type, $i = 1,..., I$; $\tau_{ad}^{y_i}$ – time for adjustment of the mold elements at y – element type; i – quantity of the elements y-th type, $i = 1,..., I$; $\tau_{la}^{y_i}$ – time for addition of lubricant in the mold element (for example, lubricant of the directing elements) at y – element type; i – quantity of the elements y-th type, $i = 1,..., I$; $\tau_r^{y_i}$ – time for repair of the fast-wearing-out mold at y – detail type (for example, a spring, the pusher) $y = 1,..., Y$; i – quantity of the elements y-th type, $i = 1,..., I$.

Time of nozzle "course" includes the following parameters:

$$\tau_{sn_i}^{\ j} =< \tau_{snf_i}^{\ j}, \tau_{snb_i}^{\ j} >, \quad (9)$$

where τ_{snf} – time the “feeding” of the nozzle; τ_{snb} – time the "withdrawal" of the nozzle. These parameters are determined by passport of IMM.

Time of the plunger / screw “course” can be described as:

$$\tau_{plu\,j_i} =< \tau_{pluf}, \tau_{p\,lub} >, \quad (10)$$

where τ_{pluf} – time plunger / screw “course” forward; $\tau_{p\,lub}$ – time of turn a plunger / screw “course” back.

Time of the plunger / screw “course” directly depends on screw speed. The melt response time in the cylinder consists from:

$$\tau_{smc_i}^{\ j} =< V_{ce}, V_{no} >, \quad (11)$$

where V_{ce} – volume of the cylinder IMM channels; V_{no} – nominal volume of IMM injection.

Nominal volume of IMM injection includes:

$$V_{no} =< V_o, K_y > , \qquad (12)$$

where V_o – estimated volume of the casting products with the sprues; K_y – coefficient considering compressibility of material and its leak on the plunger or a worm; y – IMM type, $y = 1,..., Y$.

Let's pass to the second subset of informational model (1) – time hold under pressure:

$$\tau_{hup} =< \tau_{hup}{}_i^j > . \qquad (13)$$

Time hold under pressure consists of time sequentially k-th quantity details i-th type cast at $i = 1,..., I$; $k = 1,..., K$.

The third subset of informational model (1) – time of a mold cooling which can be expressed through:

$$\tau_{cool}{}_i^j =< t_{cool}, t_M, t_c, \lambda, \delta, \tau_{cool} > , \qquad (14)$$

where t_{cool} – temperature at which the product of this design can be removed from the matrix must be sure to exclude the danger of its damage; t_M – maximum temperature of the matrix at the time of the beginning opening the mold (it is higher than the punch temperature); t_c – temperature of the melt at the time of entry into the molding cavity; λ – heat conductivity; δ – wall thickness of PP; τ_{cool} – temperature at which PP is taken from mold matrix.

The fourth subset of the information model (1) is the time taken to retrieve the product from the matrix

$$\tau_{e}{}_i^j =< \tau_{snb}, \tau_{ope}, \tau_{e}{}_i^j > . \qquad (15)$$

3. RESULT AND DISCUSSION

Having proposed the information model for determining the molding plastic products duration, it is proposed to investigate the main parameters of the model. In order to determine the molding process duration, we use universal models in accordance with formulas 1 and 2. The first to choose is a product of the "flat rectangular plate" type (Fig. 2) for molding, which offers a one-gating mold. The material of the product is polystyrene & rubber. The rubber modified with polystyrene is chosen in the way that it has a sufficiently high impact resistance [13, 14]. The investigations are carried out, the results of which are shown in Fig. 3 and the initial data in Table 1.

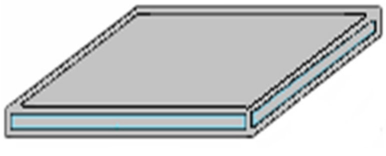

Figure 2 Type of a plastic product "flat rectangular plate"

Table 1 The values of the main parameters, which form the molding process duration

No	Parameter	Designation	Value
1	Product weight	m	19
2	time of the melt in the cylinder	τ_{smc}	2
3	time closing the mold	τ_{clo}	2
4	time plunger forward	τ_{pluf}	27
	time of hold under pressure	τ_{hup}	
5	time of turn, a plunger back	$\tau_{p\,lub}$	2
6	time of a pause	τ_{p}	3
	time of a mold opening	τ_{ope}	
7	cooling temperature	τ_{cool}	–
8	time of extraction of a product from a matrix	τ_{e}	1
9	formation process duration	τ_{fpd}	37

Results carried out a research are given in Fig. 3. In order to determine the molding process duration, we use the models in accordance with formulas 1 and 2.

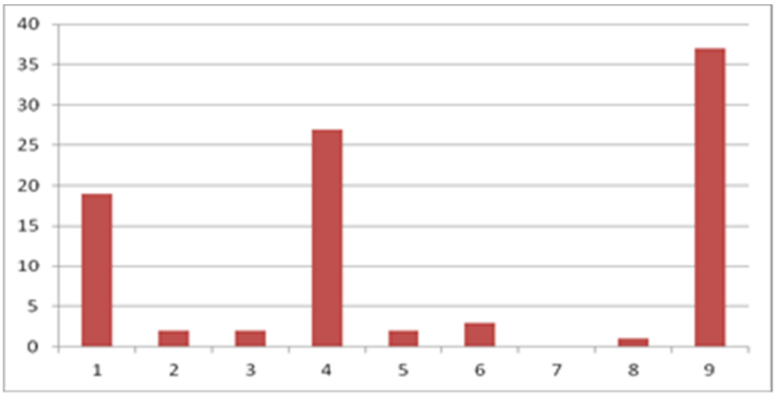

Figure 3 Formation process duration of a product "flat rectangular plate"

Further the product "basis and the toddler for light switch" (Fig. 4) for formation which one-gating mold is offered is chosen. Product material – atsetiltsellyulozny etrol. This material is chosen as it has durability, a transparence, a light fastness, a difficult flammability and small combustibility [13]. Input data's in Table 2.

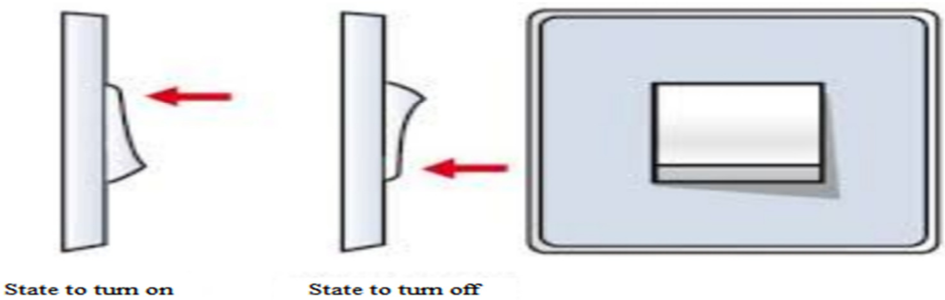

Figure 4 Type of a plastic product "basis and toddler for light switch"

Table 2 Values of the main parameters, which form the molding process duration

No	Parameter	Designation	Value
1	Product weight	m	15
2	time of the melt in the cylinder	τ_{smc}	1
3	time closing the mold	τ_{clo}	2
4	time plunger forward	τ_{pluf}	25
	time of hold under pressure	τ_{hup}	
5	time of turn, a plunger back	$\tau_{p\,lub}$	2
6	time of a pause	τ_{p}	35
	time of a mold opening	τ_{ope}	
7	cooling temperature	τ_{cool}	–
8	time feeding nozzle;	τ_{sn}	3
9	time of extraction of a product from a matrix	τ_{e}	1
10	formation process duration	τ_{fpd}	69

The results of the information model key parameters forming process duration of a plastic product such as "base and toddler for light switch" study are shown in Fig. 5.

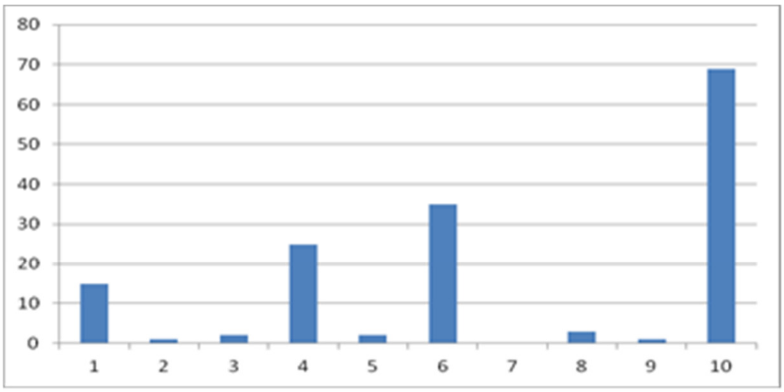

Figure 5 Formation process duration of a product “basis and toddler for light switch"

Analyzing the constructed diagrams, it was noted that the molding process duration is influenced by the holding time under pressure and the pause time.

5. CONCLUSION

On the basis of the Venn diagram, an information model of plastic products molding process duration by injection molding is constructed. IM can be the basis for a mathematical model, which makes it possible to develop a module for automated control of the molding process. The information model of FPD reflects the process parameters and the features of the injection mold service. It contains information about the elements, mutual relations and relations with the IMM.

The proposed information model differs from the existing ones in that it takes into account the time for moving the nozzle and the pause time (if necessary, performing mold maintenance).

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