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Defects of Casting Plastic Products: Causes, Recurrence, Synthesis and Ways of Elimination.

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ABSTRACT : *Plastic products are used in various spheres of human activity. These different directions are determined by the properties of the plastic. Nevertheless, the high quality of plastic products is important. To achieve quality, first of all, it is necessary to avoid defects in the casting of plastic products. We have considered the traditional approaches to the definition of casting defects molded. We also made an overview of the main defects in injection molding. The factors of deformation of plastic products were considered. The analysis of the reasons and ways of elimination of defects of plastic products is carried out. The possibility of considering various defects of plastic products in the form of a generalized binary matrix is shown. A generalized sequence of designing plastic products is proposed.*
KEYWORDS : *Plastic Products, Defects, Deformation, Binary Matrix, Parameters of Injection Molding.*

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I. INTRODUCTION

Dynamically developing market of plastics, equipment, tooling is so common that in its scope and range are superior to all other products used in modern society. Plastic products (PP) depending on the purpose can have very different shapes and sizes, so before the production of the product necessary to rationally design, but also important is their quality.

Quality control of plastic parts (castings) is the conformity indicators verification of the casting requirements quality. Quality plastic products – durability, abrasion resistance, decorative properties and special properties, such as electrical or mechanical conductivity and the like [1, 2]. Thus, under the PP as a means to obtain castings free of defects. For example, the casting defects from the design point of view [3]: products must be technological (removable) slope; tolerances for the product should be technically justified and assign them depending on the operating conditions, the magnitude of the shrinkage fluctuation polymer material and the height of the product affecting the amount of bias; if possible, you should avoid undercut depressions and protrusions; the products should not be obstacles to extract them from the mold; product design should be simplest not to use a split die and punches; the product must have a curvature that improves strength, easy to molding products and improve its appearance; wall product should be of equal thickness, with no sharp transitions.

The problem of preventing defects in the production of PP is a complex process that depends on many factors: design of the product, technology and organization of production, quality of raw materials others. The solution of this problem requires a systematic analysis, that is, a system of action, which would embrace the totality of the factors, conditions influencing the quality. An important component of such system action is to review and synthesize the various casting defects PP.

II. LITERATURE REVIEW

Today the problem of the plastic products defects and their elimination solved in many papers devoted to the molding of thermoplastics under pressure.

The work [4] devoted to the study and application of the technology for the automatic detection of surface defects on plastic products. Considered in detail the key technology of "machine vision" such as lighting systems, camera charge-coupled device (CCD), image enhancement, image segmentation, image recognition. Also briefly presents the application of the system of automatic detection for the detection of surface defects on plastic products such as electronic components, plastic, tape, building materials, PVC, film, leather, bottles and so on. detection System mainly focuses on the automatic detection of surface defects for products at the stage of injection. It consists of a special device, conveyor belt, capture software and image processing and device control by PLC.

In [5, 6] discussed in detail the peculiarities of working with Moldflow based on the conditions of molding, and injection pressure, which affect the defects of plastic products. A detailed review of defects and their causes. Consider the following defects: swelling, black spots and black stripes, brittle products, the junctions of the fin, the deviation of the dimensions of the product (precision), and discoloration burned-on food plastics, underfilling, warpage, sink marks and voids, silver streaks.

Defects on plastic products in the production process, improper training of production described in [7]. Discusses online optimization of the determining process defects through a systematic method that solves such problems, exploring the relationship between the parameters of technological process and quality of finished products. However, this method requires accurate measurement of the quality indicator, which is a difficult task for some defects, such as shrinkage and flare. In this work, a systematic method that combines digital image processing (CDIP) and model optimization (MO) to solve the general problem of preventing or minimizing defects. CDIP technology is used to control the magnitude of the surface defects. MO uses online measurements as feedback to determine the optimal parameters.

III. OVERVIEW OF THE MAIN DEFECTS OF MOLDED PRODUCTS

The causes of marriage on the products can be correctly specified parameters of the machine and process, and a wrong design of the mould and the moulded product. The quality of molded parts is often valued only for their appearance. With proper selection of molding conditions, design details and design of the mold products from thermoplastic materials have a smooth and shiny surface.

Often on the injection products, there are dark stripes/spots, this is due to overheating the thermoplastics or bad its mastication. In the case of heterogeneous plasticizing of the thermoplastic product can remain unmelted particles. This defect in the form of spots, the size of which is close to the size of granules can be seen in transmitted light. Sometimes a particle can be distinguished as a faint bulge on the surface of the product.

The silver stripes are the signs of a gas bubble, which is spread on the surface of the product. The occurrence of silver streaks can be caused by excessive moisture content or air that is captured along with the granules and under adverse conditions is not fully removed by plasticizing.

Dents or minor irregularities do surface similar to orange peel. These defects arise from an insufficient pressure during casting, resulting in incomplete contact with the surface of the mold.

Matte, white, folds near the inlet of the Gating of the channel can occur due to too rapid cooling of the melt. These defects arise due to formation of a very thin sheath near the walls of the mold, while the mold cavity is still filled. This shell is in the process of filling form is exposed to various influences, if it is stretched, the object is white or cloudy, if it breaks and is displaced, then there will be folds.

The greatest degree of warpage observed: large flat items that do not have ribs; the products with different thickness or articles with one-way valves; in the mismatch conditions.

Cracks occur due to: excessive internal stresses in the products with a significant thickness variation; the lack of curvature sufficient radii; incorrect installation of the metal reinforcement.

Cracks and warping can occur immediately after manufacture of the product, and in the process of its operation. Table 1 shows some of the common defects in injection molding and the possible causes for them.

IV. SHRINKAGE AS THE DEFORMATION FACTOR OF PP

Shrinkage is the main factor determining the accuracy of the product [8]. Under the shrinkage understand the absolute or relative reduction in the size of the products compared to the size of the cavity gating of the form:

Distinguish between shrinkage absolute (Sh_a) and relative (Sh_r) [9]:

$$Sh_a = d_{dp} - d_{pp} \qquad (1)$$

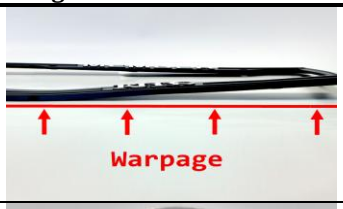
$$Sh_r = \frac{l_n - l_u}{l_n} \cdot 100\% \qquad (2)$$

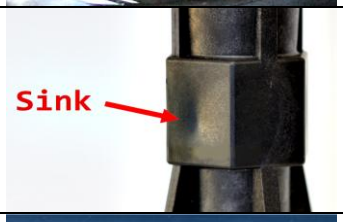
Where

d_{dp} – the dimensions of the drawing parts.

d_{pp} – the sizes of plastic products.

Table 1: Main defects of molded products

№	Defect	Image	Possible causes
1	Warpage		A differential cooling rate of the melt in two sections of the molded product [1, 2, 6]
2	Weld Lines		The melt flow front is usually cold due to the exposure to the cold cavity. When two flow fronts meet as in a flow around a mold pin they do not fuse uniformly causing a weld line. Sometimes air can also get trapped in to form the defect [2, 6]
3	Short Shot		Molten Plastic is not reaching the mold cavity section [2, 6]
4	Gate Blush		Shows up at the gate when the material is sheared differently compared to the rest of the part [2, 3, 6]
5	Bubbles		When moisture and/or a gaseous byproduct gets mixed with the melt and is injected in the mold cavity this moisture or gas if embedded inside the melt can show up as bubbles [2, 6]
6	Voids		Usually occur with the parts are thick. The walls solidify and the plastic melt shrinks towards the wall and therefore sucks a vacuum void on the inside of the part [2, 3, 6]

7	Burn Marks		When air and gasses get trapped inside the mold cavity during plastic injection, the high pressure results in the dieseling of the plastic resulting in the burning of the plastic [2, 6]
8	Splay		A layer/ streak of a unwanted gaseous byproduct from the melt or moisture in the material comes in between the melt flow and the cavity walls preventing the texture from being picked up and in addition eventually leaving a residue [2, 6]
9	Sink		Plastic is shrinking as it cools but additional plastic cannot be for further compensation of the shrinkage [2, 6]
10	Flash		Molten plastic is flowing into unwanted sections of the mold cavity [1, 2, 6]

Shrinkage occurs in three stages. The first and second stages occur in the injection molding form from the date of filling the form to delete the product. And the third stage occurs after removal of the product from the mold upon cooling to ambient temperature [9].

Shrinkage in the first stage will be determined by the pressure in the form. While holding pressure, the material temperature decreases and the density increases. However, continuous feeding of the melt in the form of stops. The increase in the temperature of the product and continuous compaction of the material occurs until then, until the thermoplastic hardens in the inlet channel.

Then begins the second stage. Flow of the melt in the form does not occur, and the temperature of the material does not change. Under these conditions the shrinkage of the polymer occurs due to thermal contractions, it would depend on the cooling rate. The lower the mold temperature, the lower the shrinkage of thermoplastics [10].

In the third stage, after the removal of the product from the mold, a free shrinkage happens. The decrease in the volume of the product is determined by the difference between the temperature at which the product was extracted from the mold and ambient temperature, and volumetric coefficient of thermal expansion.

The estimated shrinkage determined by the formula:

$$V_p = V_{зо} \cdot \beta \cdot (t_ф - t_к), \qquad (3)$$

where

$V_{зо}$ – the volume of sample within 30 minutes after removing from the mold.

β – the volumetric coefficient of thermal expansion.

$t_ф$ – the temperature of the mold.

$t_к$ – room temperature (25°C).

Thus, when considering defects PP, special attention must be given to the shrinkage factor at different stages of thermoplastics moulding technology under pressure.

V. RESULTS AND DISCUSSION

5.1 Many Defects PP as Generalized Binary Matrix

The process of casting under pressure is prone to failure, which can significantly influence the quality of plastic products. Short interruptions cause long-term unbalance. Therefore, the same conditions of injection molding, e.g., injection and thermal equilibrium can be sustained only with a certain probability. On the basis of the review of defects in plastic products obtained by injection molding this process is proposed to describe the binary matrix the main types of defects in the PP are presented in Table 2.

Table 2: Main types of defects PP

Defect	Stage of the casting process under pressure					The parameters of the mold				The parameters of the IMM	Material
	PL	IN	MU	FCO	RM	Gt	Du	St	t		
Antifogging inclusion	1	1	0	0	0	1	0	0	0	1	0
Colorful inclusion	1	1	0	0	0	1	0	0	0	1	1
Incorporating fiberglass	1	1	0	0	0	1	0	0	0	0	1
Tightening	0	0	1	0	0	1	0	0	0	0	0
Gloss, unevenness of gloss	1	1	1	0	0	1	1	0	0	0	0
Lines, cold joints, traces the flow of	1	1	1	0	0	1	1	0	0	0	0
The formation "free jets"	0	1	0	0	0	1	0	0	0	0	1
Visible imprints of the ejector	0	0	1	0	1	1	0	0	0	0	0
The effect of "records"	0	1	0	0	0	1	0	0	1	0	0
Dark spots	1	0	0	0	0	0	0	0	0	0	0
Dim areas in the area of the gate	1	1	0	0	0	1	0	0	0	0	0
The stratification of the surface	1	0	0	0	0	0	0	0	0	0	1
Cold tube, the lines are cold of course	1	1	0	0	0	1	0	0	0	0	1
Incomplete fill	1	1	1	0	0	1	1	0	0	1	1
Excess fill (scaly, fin)	1	1	1	1	0	0	0	1	0	1	1
Deformation when removing products from the mold	1	1	1	1	0	1	0	0	0	0	0
Increased thickness of the products	1	1	1	1	1	0	0	0	1	1	0
The fluctuation in the dimensions of the product	1	1	1	0	0	1	0	1	0	1	0
The swing weight products	1	1	0	0	0	0	0	0	0	1	0
Cracking due to internal stresses	1	1	1	0	0	0	0	0	0	0	0
The inclusion of air bubbles	1	1	0	0	0	1	0	0	0	0	0
Shrinkage	0	0	1	0	0	1	0	0	0	0	0
Thermal damage	1	0	0	0	0	1	0	0	0	0	0

In Table 2: PL – plasticization; IN – injection, MU – makeup; FCO – force closing / opening the mold, RM – removing from the molds, MD – the mold, IMM – injection molding machine, Gt – gate; Du – ducted air

from the mold, St – stability, t – temperature, 1 – means the occurrence of a defect due to the parameters of the casting process or due to the features of the mold / injection molding machines, 0 – means that this parameter / factor does not affect the appearance of the defect.

If we consider the defect such as "shrinkage" (air inclusion), then at the Table 2, the value "1" is located in the columns to the makeup (MU) and the gate (Gt) means that it is necessary to adjust the phase of recharge and pay attention to the design / location of the gating system. According to Table 2 shows that the other cells is set to "0", that is, these parameters / factors do not affect this defect. We consider in detail the appearance, for example, such a defect – incomplete filling (underfill), which, as shown in Table 2 arises due to modes that arise during plasticizing (PL), injection parameters (IN); singularities makeup (MU). Also, the appearance of this defect is affected by the design / location / number of sprues and the method of extracting air from the mold. Important if you experience partial fills are the parameters of injection molding machines, but also the properties of the material from which it is crystallized detail, are also one of the main reasons for the occurrence of this defect.

Table 2 also shows:

– Inclusions: dirt, plot (area) a different structure and composition [8].
– Antifogging inclusion: rougher brownish coloration of the inclusion (region) rounded.
– Incorporating fiberglass: tougher glass includes a rounded shape.
– Colorful inclusion: colored coarser elongated inclusions in the form of a line.

The effect of "records" – a surface with grooves that are formed in accordance with the direction of the melt flow front (Figure 1) [11]. On the edge of the channel in such surface defects have resemblance with the grooves of the record. Mostly at the very end of the melt flow.

Figure 1: The form of "records" PP

Table 2 shows antifogging and colorful inclusion for these defects, the value "1" is in cell PL, IN, Gt and IMM parameters, it is necessary to control the stages of the plasticizing, injection and the parameters of the gating system and the parameters of the IMM. But the appearance of colorful inclusions is also affected by material properties which indicates “0” value in the «Material» cell.

As for incorporating fiberglass, the antifogging and colorful inclusion is set to "1" in the «Material» cell and "1" in the IMM cell, that is, the effect of these settings is significant and needs to be monitored. Considering plastic as raw material and as the material, the heterogeneity of material properties is not always acceptable and often leads to marriage (for instability of the physical properties, dimensions, warping, cracking) [12].`

The products made by casting under pressure, often there is deviation of form from the cavity shape, the part curvature. The most commonly bent flat parts. The durability of thermoplastics to the curvature depends on the parameters of casting process, design of products and moulds, of the difference between radial and tangential shrinkage, which, in turn, caused by molecular orientation of thermoplastics. Shrinkage in the flow direction more than in the perpendicular direction, as the number of macromolecules, oriented perpendicular to the direction of the current, much smaller. To receive the unbent parts, need to choose the right mode of casting, to choose the right material, to ensure the correct location of the intake.

In order to determine the cause, you must first localize and accurately determine the defect (that is, what he looks like, where, when and how often is). To accomplish this, you need to know the machine parameters injection molding machines and process, therefore, developed a matrix of defects.

5.2 Causes and Elimination of Defects PP

Thus, the result of the above determined that a large impact on all types of defects have the shape design and molded products, while factors such as clamping force, disclosure forms and the extraction of products from

forms play a secondary role. Then you need to organize, at what stage of the casting process may be defect. These issues are reflected in the Table 3.

Table 3: The causes and ways of elimination of defects, PP, obtained by casting under pressure

Defect	The cause of the defect	Solution
Stripes and elongated bubbles on the surface of the product	Material moisture	Drying of raw materials
Matt spots on the surface of the product	Overheating of the melt	Reducing the temperature of the melt
Dark streaks on the surface of the product	Local overheating of the material; the presence of dead zones in the cylinder or in the nozzle	Reducing the temperature of the melt
Dark stains and air bubbles	Not promptly removed trapped in the cylinder the air	The increased pressure of the plasticizing
Voids in the product	Strong heating (compression) of air trapped in the form	Improvement of the air output from the cavity of the mold; the speed reduction; injection and temperature; material
Local burnout details	Strong heating of the trapped in the form of air, compressing it, and as a result, burnout of the material	
Contamination of the product	Getting into the material, foreign particles or scoring on the surface of the cylinder, piston or screw	Monitoring of the purity of the material entering the hopper
Film or spots on the surface of the part	The contact of the melt with the oil; excessive lubrication of the mold	Check the purity of the injection cylinder; cleaning mold, reduction of grease
Short shot	Small batch injection; low melt temperature; low speed injection; insufficient injection pressure; insufficient wall thickness of the product; uneven filling of the form	Accordingly, the increase in the portion of injection, temperature of melt, temperature, injection rate, pressure die casting, wall thickness; test mode form fill, change the direction of melt flow
Voids, cavities, sink	Partial compensation of shrinkage upon exposure of material under pressure	The increase in the loaded portion, the exposure time of the material in the mold under pressure
Wavy surface remote from the sprue of the product	The cooling of the melt in the process flow	The temperature rise of the material and injection rate
Seams and folds near the gate	Excessively rapid cooling of the melt in the area around the gate	The temperature increase of the mold around the gate; the increase of the dimensions of gating channels
Bubbles in the form of white inclusions	High temperature cylinder and the low pressure die casting; insufficient exposure time of the material in the mould under pressure	Decrease cylinder temperature, increase in pressure of molding and time of exposure to pressure; increasing the size of the sprue or gating of the channels to reduce pressure loss
Warping products	Incorrect temperature regime of processing; the unfortunate location of the sprue	The increase in cooling time of the product; reducing the temperature of material and mold; Thermal damage products; change the location of the gate

Welds	Excessive cooling of the melt when filling out the form	The increase in the temperature of the mold and the material, speed of injection, pressure die casting; change the location of the gate (to change the direction of flow of the melt)
Exfoliation of the outer layer details	The inclusion of foreign materials	Cleaning of the cylinder and nozzle from debris
Grat product	Insufficient locking force of the mold; the violation of the mold contact surfaces parallelism	Accordingly, the increase in the clamping force of the mold or reducing the rate of injection and pressure molding; verifying the tightening of the columns in the formation of the burr on one side of the product; the decrease in the loaded portion of; check the parallelism of the contact surfaces of molds; the decrease in the secondary pressure forming
Difficulties when removing the products; the deformation of the product during the removal of	Incorrect mode of casting, improper design of the mold	The reduction of pressure casting, the increase in taper of the walls of the molds or cores; polishing the surface of molds

5.3 Generalized Design Sequence PP

The design of the PP must provide a place for supplying gate, the position of the ejectors, traces of inserts and the location of the parting line of the forming elements.

The location of the intake channel gating influences the character of the melt flow in the form of internal stresses, the formation of junctions in a product, traces of flow on the surface of the product, shrinkage, deformation of the product at high temperatures, the strength of the product. Internal stress is usually the most significant in the area of the inlet, so the inlets in the product are the most dangerous and prone to cracking or destruction. The location of the lines of the junctions depends on the location of the inlet, thickness and part complexity. Improper location of the intake can distort the shape of the casting. It is necessary to create conditions for parallel flow of polymer into the cavity. Therefore, the process design of plastic products should maximize manufacturability of the design. This involves the achievement of minimum cost, material savings, simplified design of the molding tool, improving the reliability and durability of the part. However, the main problem of automating the design of any PP is an adequate simulation of the object and process of design. The problem is that the designer, using computer storage and processing of information, should present a clear mathematical formulation of the design problem, the graphics object model of the design and logical model of a sequence of projecting in detail the content and sequence of actions, so that model became the basis for the drawing up of algorithm of functioning of the program. Therefore, a generalized design sequence PP should be presented in the form of a block diagram in Figure 2.

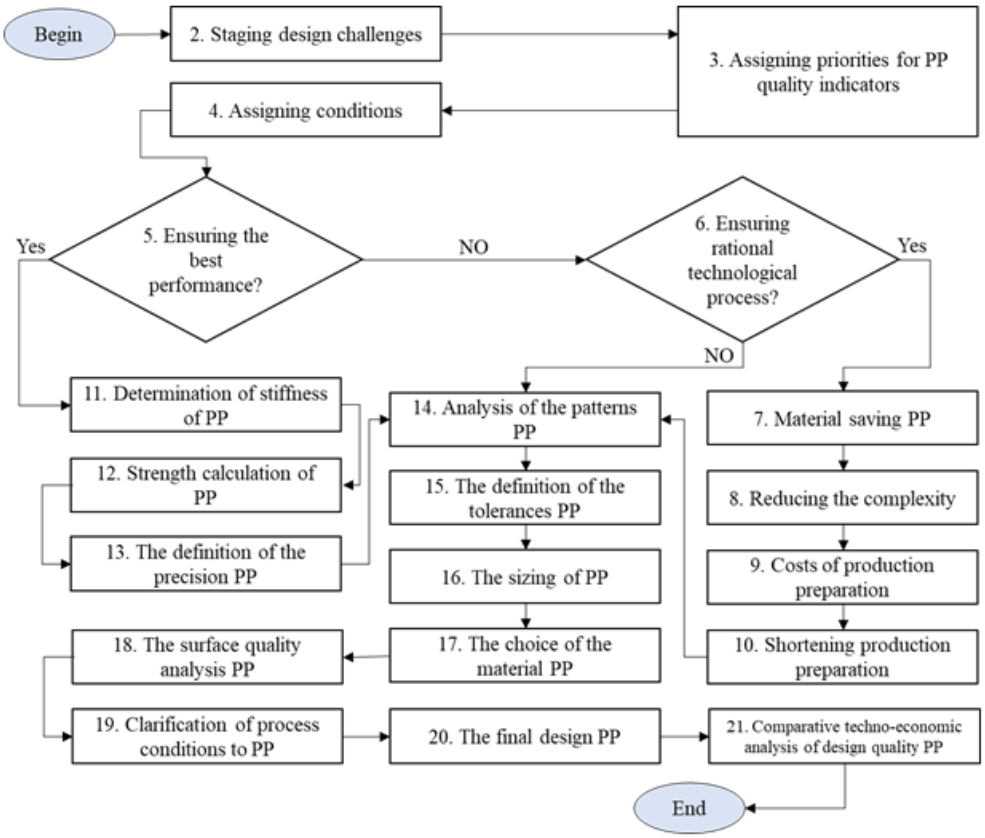


Figure 2: Generalized design sequence PP

When designing a PP should also take into account production capabilities of the company, as the design can be quite sophisticated, but for a number of reasons (large size and weight, complex configuration requiring the use of mechanized molds, and others) in the enterprise cannot be made.

5.4 Factors Influencing the Formation of Defects in the PP

Our results also allow us to make generalizations about the most influential factors (stages of the forming process, mold design, materials, and IMM parameters) on the formation of defects, PP, obtained by casting under pressure. The results of these studies are presented in Figure 3.

On the x-axis readout 1...5, which mean:

1. for study 1, where the factors influencing the occurrence of defects (the steps of molding under pressure represented in blue color):

– 1: a defect that occurs when removing the castings from mold (RM).
– 2: the defect that occurs when closing / opening mold (FCO).
– 3: the defect occurring on stage makeup (MU).
– 4: a defect that occurs at the stage of injection (IN).
– 5: the defect occurring on the stage plasticizing (PL).

2. for study 2, where the factors influencing the occurrence of defects (the parameters of the mold represented in violet color):

– 1: the defect is caused by irrational choice of temperature (t).
– 2: the defect that occurs due to the instability of (St).
– 3: defects arising due to ducted air from the mold (Du).
– 4: a defect that occurs due to the gating system (Gt).

3. for study 3, where the factors influencing the occurrence of defects (parameters of represented in orange color):

– 1: the defect arises due to faulty choice of the parameters of the injection molding machine.

4. for study 4, where the factors influencing the occurrence of defects (material, namely plastic represented in pink color):

– 1: a defect resulting from inappropriate material selection.

Numeric values range from 1 to 18 represented on the y-axis are the number of the defects arising in the casting which were previously detailed in Table 2.
Thus, we can conclude that the greatest influence on the appearance of defects in plastics is due to the following: stages of the casting process under pressure, plasticization and injection, as well as a significant parameter of the mold is gating system.

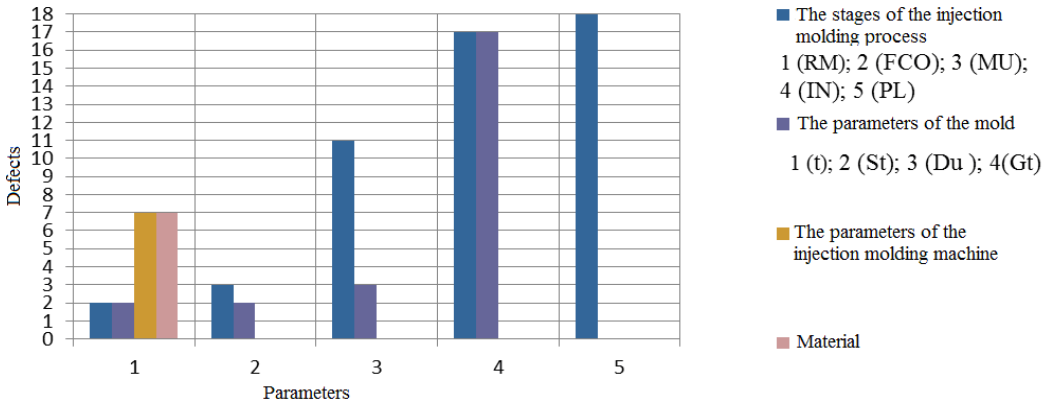


Figure 3: A histogram of influences on forming process stages

Availability of necessary information at the right time is essential in the design and operation of PP, and also very important when designing molds. Rational form of providing the necessary information about the casting process and equipment creates the basis for optimum life cycle plastic products. The proposed formalization of defects in the form of binary matrix in general is to determine the causes of the defect to control and ultimately prevention. This form of reporting defects differs from the existing, the fact that it is convenient for the manipulation of information about the quality of the items received. Full consistency of the design plastic products and molds, processing conditions of raw materials and parameters of the forming process requires experience in order to achieve optimal results in a fast elimination of defects in injection molding of plastics. On the basis of a single specific case has to be decided, you need a simple or surgical elimination of the defect (for example, a change in the parameters of IMM), or the intervention required in the design of the product, and accordingly, the design of the mold and gating system.

VI. CONCLUSION

As a result of the plastic products defects review were determined that the surface defects mainly laid on the stage of the plasticizing and injection. Defects tolerances and unsatisfactory mechanical properties of the products formed, mainly, by plasticizing, injection and so on. The proposed binary matrix main types of defects of plastic products. This formalization of defects is of particular importance, as it mainly affects the structure of the storage and transfer of primary and secondary information when solving problems of quality assurance PP.

Presents a generalized block diagram of the sequence of design PP which reflects a clear model of the sequence of measuring, computing and logical operations in order to implement the tasks of each unit. In the course of the review were identified causes of defects in plastic articles and methods of their elimination. The influence of the stages of the forming process, design of molds, material, and IMM parameters on defects. The result is a histogram that displayed the most often when defects occur (the stages of the plasticizing and injection), and also showed that a significant factor influencing the defect is a gating system.

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