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QUALITY MANAGEMENT OF THE PRODUCTION OF PLASTIC INJECTION MOLDING TOOLS

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Abstract: Quality management is a continuous and dynamic approach to business that seeks to increase the quality, competitiveness and productivity of the organization through the process of continuous improvement of the quality of products, services, processes, people and the environment. The production of plastic injection molding tools is characterized by single production and high product prices. Mistakes in the process of development, design and production of tools most often lead to high costs, non–fulfillment of agreed delivery dates and loss of image with the customer. Because of this, the manufacturer should establish an effective quality management system in its processes, and especially the quality control subsystem. In modern production, product quality control is indispensable and is imposed as a mandatory function of the organization. Controlling and testing of the product during the process of its creation and delivery to the customer is carried out according to pre–defined control points and characteristics for control. These elements are defined in the process of design and technological preparation and are an integral part of the appropriate control documentation. Adequate application of control documentation improves product quality, identifying sources of variation in individual processes and establishing controls for their monitoring. This has the effect of increasing customer satisfaction, reducing waste and improving the financial results of the business. The aim of this paper is to analyze the processes of making plastic injection molding tools and to define and implement the control documentation required for their production.

Keywords: quality, molding tools, control documentation

1. INTRODUCTION

The design and introduction of quality systems in industry and other areas of the economy is carried out by implementing a selected standardized model in the conditions of real industrial systems. Standards set requirements in the form of standardized work procedures that companies should include in the performance of business processes and that as a result have a certain quality of functioning of the company as a whole. The basic direction in the design of quality systems in business systems should be based on a systemic approach with the use of process models and methods and techniques provided by systems theory and information theory.

The business system maintains the development process if its processes of monitoring, measuring, analysing and evaluating performance are carried out successfully. With their help, it is possible to determine the efficiency and effectiveness of the system and make appropriate management decisions. Depending on the type and structure of the business system and the application of business practices, the documentation of the quality management system can differ significantly. An integral part of the documentation of the quality management system is also the control documentation, which is used for testing and controlling the product during its creation and delivery to the customer.

Failure Mode and Effects Analysis – FMEA is one of the risk analysis techniques that provides an analysis of potential errors, identifies the severity of their consequences, determines priorities for the implementation of corrective measures, affects the reduction of waste, processing and production costs, the number of customer failures and warranty costs [1].

In the long term, the FMEA method develops criteria for planning and designing the quality system (provides inputs for the production of control documentation), provides documentation for future reliability analyses in case of system changes, and provides a basis for maintenance planning [2].

2. CONTROL DOCUMENTATION

Controlling and testing of the product during its creation and delivery to the customer is carried out according to pre–defined control points and characteristics for control. Adequate application of control documentation improves product quality, identifying sources of variation in certain processes and establishing controls for their monitoring, which affects the increase of customer satisfaction, reduction of waste and improvement of financial results of operations. Control documentation is focused on processes, operations, and product features that are most important to the customer. To define the control documentation of a specific product, it is necessary to provide appropriate inputs, which are most often: construction drawings, product standards, manufacturing process, deposited samples, production program distribution, production norms, analysis of non–conformities from the previous period, etc. Criteria for control and supervision, as well as suitable methods and techniques, are chosen based on the previously assessed ability of individual processes, bearing in mind the economic parameters of control

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operations. The control documentation specifies the intended methods and techniques, sampling and acceptance criteria, and the necessary measuring equipment. The control documentation includes the following documents [3]:

— Quality plans,
— Control plans,
— Technological procedures of the control,
— Checklists,
— Instructions for control and others.

Depending on the type of product, applied production technologies, customer requirements, standard requirements, number of available quality controllers and other conditions, the company creates the necessary control documentation.

Quality plan

The quality plan is a comprehensive document for the quality management of a specific product or a group of similar products, a service or a project, which includes processes from the customer's request to the monitoring of the customer's satisfaction with the delivered product/service. It shows the implementation processes, responsibilities, procedures and instructions for their implementation, as well as the records that should be created. They may also contain important characteristics that are monitored on the product/service and processes [3].

Control plan

A control plan is a document that contains detailed procedures that describe how control operations will be carried out and monitored [3]. The control plan is most often created for products that are subject to the traceability procedure, more complex products or at the customer's request. It is often identified with the quality plan, although it is usually one of its outputs. The control plan defines the control operations according to the sequence of execution for certain product realization processes. When selecting control operations and characteristics to be monitored, certain risk analysis methods (FMEA, FTA, ETA, etc.) are usually used. Often, instead of a control plan, organizations create control instructions that describe the control procedure in detail with all the necessary information.

Technological procedures of the control

The technological procedures of the control needs to be done with more complex product control operations, when there is a doubt that the control will not be successfully implemented without a detailed presentation of the control operation [3]. In addition to the label and name of the product, the characteristic to be controlled (its labels, required values with tolerance, measured values), control mode and means of control, the technological procedures of the control also contains the following data:

— The necessary sketch or picture of the part with the specified control dimensions (often the same picture also shows the correct position of placing the control means, i.e. the control method),
— A brief description of the activity (phase of control to be carried out and characteristics to be controlled).

Checklist

A checklist is a document in which the results of product and process control are entered. Its form can be different depending on whether it is intended for recording the value of controlling only one measurement characteristic on products from the sample (e.g. measuring the thickness of the surface protection layer on a sample of products taken from one batch) or for recording all defined measurement characteristics on one product in the course of its production or for the summary display of the number of non–compliant products by type of error within certain series at 100% control, etc. [3]. It can have a form identical to technological procedures of the control.

3. MONITORING THE QUALITY OF THE PRODUCTION OF PLASTIC INJECTION MOLDING TOOLS IN THE COMPANY MANDEKS MOLDING D.O.O.

The company Mandex Molding d.o.o. was founded in 2018 in the municipality of Laktaši BiH, when it started the production of tools. The main activity of the company is the development, design, production and sale of tools for punching and cutting and plastic injection molding.

Plastic injection molding tools

Making tools is an extremely complex job that requires a high level of knowledge and great responsibility and commitment from the engineers themselves and all the workers. Plastic injection molding is a cyclic

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process of primary polymer molding that is performed by injecting a molten polymer of a certain viscosity from an injection unit into a tempered mold. The workpiece hardens in the mold by cooling in the case of thermoplastic materials or by cross–linking in the case of elastomers, elastoplastomers and duromers, followed by ejection from the mold.

The plastic injection molding tool is one of the basic elements of the injection molding system, which directly shapes the workpiece. In addition to the choice of materials, the design of tools and processes significantly affect the properties of injection molded parts. Dimensional accuracy and good microstructure formation and their interaction are particularly important for adequate mechanical and tribological properties, i.e. production of high–quality components [4]. The tool should meet the following requirements:

- Technological: during one work cycle, completely shape one or more products and take the liquid mass, distribute it through the mold, fill the cavities, cool, convert the mass into a solid state and eject the product.
- Structural: it is necessary to take over the forces during injection molding, to ensure the rigidity of the structure, to ensure adequate closing and opening of the tool, to ensure the repeatability of the positioning of the tool, efficient ejection of the product.
- Functional: it is necessary to provide systems for pouring, forming, tempering, ejection, guiding, cantering, receiving, side formers, locking [5]. On the Figure 1 plastic injection molding tool "DOOR 2x36DIN" is shown.

FMEA analysis of the plastic injection molding tool manufacturing process

The goal of conducting an FMEA analysis of plastic injection molding tools is to prevent possible failures/mistakes that can potentially cost the company dearly and significantly prolong the tool manufacturing process. The FMEA analysis is the basis for the creation of a control plan, which will be applied in the creation of any plastic injection tool. The process of making plastic injection molding tools consists of several stages: development, design, procurement of materials, production and delivery. A detailed FMEA analysis covers all given processes, and Figure 2 shows the FMEA segment related to the milling process during the production of movable and immovable form plates as the two most complex parts where the most errors occur.

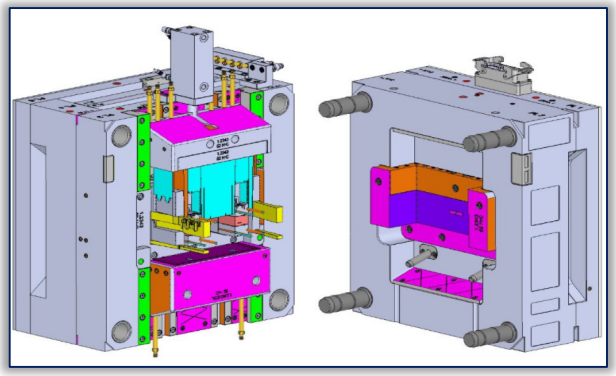

Figure 1. Plastic injection molding tool "DOOR 2x36DIN"

FMEA analysis

Product group/Product: **Plastic injection molding tools/ Plate of movable and immovable form**		FMEA number: 001.21.42	
Team: Miroslav Lukić, Bojan Vukmiorvić, Jovan Marić		Date FMEA: (Initially)	03.06.2021.
Moderator: Jovan Marić		Date FMEA: (Review)	24.06.2021.

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FMEA process												Action results					
NUMBER	PROCESS OR OPERATION	POTENTIAL FAILURES/ ERRORS	POTENTIAL EFFECTS OF FAILURES/ ERRORS	S	POTENTIAL CAUSES OF FAILURE/ERRORS	O	FAILURE/ERROR PREVENTION METHODS	FAILURE/ERROR DETECTION METHODS	D	RPN	RECOMMENDED MEASURES	RESPONSIBILITY AND DEADLINE	MEASURES TAKEN	S	O	D	RPN
4.	Milling	Tool calibration error	Length tolerances will not be respected during processing	5	Carelessness of the operator when calibrating the tool	4			4	80	Tool calibration control	Operator from the 03.06.2021					
5.	Milling	Tool dullness	The specified tolerances will not be respected during processing	6	Lack of tool control, poor tool quality	4			3	72	Greater tool control, operator training	Operator, managem. from 03.06.2021					
6.	Milling	After processing, required measurem. within tolerances	Rework of pieces required, cost increase, delivery delay	3	Operator carelessness, bad tools, G-code entry errors, lack of control	1			3	9	Introduction of control documentation	Operator, managem. 15.06.2021					

Figure 2. Part of the FMEA analysis of the plastic injection molding tools

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Control documentation for the production of plastic injection tools

After the FMEA analysis, created as a result of the prevention of high–risk errors, the Control Plan for plastic injection molding tools was introduced, shown in Figure 3.

The control plan for plastic injection molding tools envisages the introduction of a technological control procedure for complex measurement operations. Figure 4 shows the technological procedures of the control for the complex contour control operation on the Door 2X36 DIN tool with the entered measurement results of the required characteristics from the tool making process. The tool prepared for delivery to the customer is shown in Figure 5.

CONTROL PLAN

Product group/Product: **Plastic injection molding tools/ Plate of movable and immovable form**

Control plan number: 21-1/10

Proc./ operation num.	The name of the process/ operation	Machine/ device	Characteristics			Methods					Corrections
			Num.	Product	Process	Specification of product/process tolerances	Measurement technique	Control mode: Sample size	Control mode: Freq.	Data register	
1.	Procurement			Materials, finished parts	Ordering	Perform control: dimension, quantity and order specification, material certificate				Checklist (KL2)	
2.	Deep drilling	Cantilever drill		Plate of movable and immovable form	Control of given tolerated dimensions	According to the workshop drawing, perform the control of the tolerated dimensions	Using measuring equipment			Measurement Checklist (ML6)	
3.	Milling	Milling machine HAAS	1.	Plate of movable and immovable form	Control of given tolerated dimensions	According to the workshop drawing, perform the control of the tolerated dimensions	Measuring with a sliding sc., to reporter, mach. tools			Measurement Checklist (ML6)	
		Milling machine HAAS	2.	Plate of movable and immovable form	Control of a complex contour	The control shall be carried out using the prescribed technological control procedure	Using a machine tool as a measuring machine			Technol. procedure of the control (TP7)	
4.	Electroerosion (EDM)	Erosimat	3.	Plate of movable and immovable form	Control of given tolerated dimensions	According to the workshop drawing, perform the control of the tolerated dimensions	Measuring with a sliding sc., to reporters and mach. tools			Measurement Checklist (ML7)	
		Erosimat	4.	Plate of movable and immovable form	Control of a complex contour	The control shall be carried out using the prescribed technological control procedure, perform a preliminary control on the milling machine when making the electrode for EDM	Using the machine when measuring			Technological procedure of the control (TP8)	
5.	Final processing			Tool	Assembly of tools	Check according to the product composition				Checklist (KL2)	

Figure 3. Control Plan for plastic injection molding tools

TECHNOLOGICAL PROCEDURE OF THE CONTROL

Label: 063/21-IMS
Date: 7. 6. 2021.
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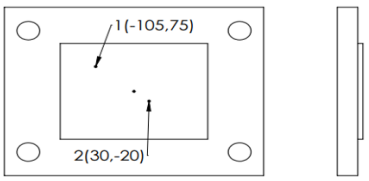
PRODUCT NAME: DOOR 2X36 DIN TOOL Movable form plate — Product label: P.P.F.001.21

Material of the product	Standard	Traceability mark
Tool steel		2019-8-27-PR

DESCRIPTION OF CONTROL OPERATION:
Check the profile on the movable form, check it with the machine tool using the measuring tool, in relation to the reference point, locate the assigned values along the X and Y axes, then lower it along the Z axis until it comes into contact with the tool profile. After contact, write down the measured value and compare it with the requested one.



Operation/ characteristic label	A controlled feature	Required value	Measured value	Feature importance class	Control mode	A means of control
2/1	Dimension according to drawing A02.01.01	+0,02 12,62 -0	12,63	A	100%	Machine tool
2/2	Dimension according to drawing A02.01.01	+0,02 13,87 -0	13,89	A	100%	Machine tool

Figure 4. Technological procedures of the control for the complex contour control operation on the Door 2X36 DIN tool

Figure 5. Tool prepared for delivery to the customer

4. CONCLUSION

In today's time of global competition and modern production, quality along with price has become a decisive factor in the market. Quality is also extremely important for companies whose main activity is the

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development, design, production and sale of tools for injection molding of plastics and tools for punching and cutting. Buyers of these products are very demanding and almost do not tolerate mistakes and deviations from the agreed production deadlines.

In order to achieve the quality of the product required by the customer and to reduce the possibility of errors in the work, the procedure for creating control documentation for the selected group of products, in this case plastic injection tools, is presented. In the first phase, all important processes for the realization of a given group of products were identified, then possible errors in the given processes and their risk levels were identified using the FMEA analysis. In the second phase, control documentation (control plan, technological procedures of the control, control lists, etc.) was created, and part of it is presented in the paper. The created documentation was successfully implemented in the process of making for injection molding tool of cabinet doors DX36 DIN. The demonstration procedure for creating control documentation and its form can, with minor adjustments, be applied to the creation of other products.

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