ANALYSIS OF THE APPLICATION OF FMEA METHOD OF WEREHOUSE SYSTEM IN METAL FOUNDRY

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Abstract

The paper presents the analysis of the application of FMEA method of storage system in the area of a metallurgical enterprise performing gray iron castings according to the PN-EN 1561: 2000 and PN-92 / H-83101 standards as well as alloy cast iron. Casting is a technology for making objects by filling molds with liquid metal. Castings are made of cast steel, cast iron, aluminium, magnesium and copper alloys. The casting technology could be used to form objects of very complex shapes with very high accuracy, eg pistons, motors, casings, tools. The aim of the publication is to realize the FMEA method of the warehouse system so as to find the causes of defects, to remove errors and to commit repair tasks, so that the whole planning and storage process takes place in an effective manner, while reducing the criticality priority of defects in all cases. After performing the FMEA analysis all the defects, causes and effects occurring in the process were determined from demand for goods planning up to delivery and quantitative and qualitative control. Ishikawa's cause-effect diagrams were used to detect the exact causes of the most important defects in the process and then corrective actions were recommended. Among the six included actions of the process the two most difficult actions were identified which should be addressed first. An effective solution for these two process activities is the systematic update of the list of preferred suppliers and the employment of an auxiliary employee supervising and approving the procurement plan.

Keywords: Metal foundry, grey and alloy cast iron, Mode and Effects Analysis, warehouse system, importance of defects, failure

1. INTRODUCTION

The paper is to present an analysis of the application of FMEA method of the storage system in the area of a metallurgical enterprise performing gray iron castings according to PN-EN 1561: 2000 from the GJL150, GJL200, GJL250, GJL300, GJL350 and PN-92 / H-83101 of types ZL150, ZL200 grade, ZL250, ZL300 and ZL350 as well as cast iron alloys - mainly chromium. Occasionally, a company engaged in the steel castings. The casting is carried out in the weight range from 2 kg to 150 kg. In addition, the plant provides services in the field of machining, plasma metal cutting and MIG / MAG / TIG welding [12].

Casting is a technology for making objects by filling molds with liquid metal [5]. Castings are made of cast steel, cast iron, aluminium, magnesium and copper alloys [1]. Casting is used when other technologies are too expensive [8]. Casting technology could be used to form objects with very complex shapes with very high accuracy, eg pistons, motors, housings, tools. [11]. The aim of the publication is to realize the FMEA method of the warehouse system so as to find the causes of defects, to remove errors and to commit repair tasks, so that the whole planning and storage process takes place in an effective manner, while reducing the criticality priority of defects in all cases. The use of the FMEA method and tools is mainly intended to maintain adequate product quality, as well as to eliminate defects and non-conformities in the initial phase of production and not during operation by the customer [4,9]. Finding defects in the product after the purchase makes customers submit complaints and warranty claims, which causes a decrease in credibility and reduce the quality of the finished products offered [3]. Such a situation leads to responsibility of bearing significant costs related to the elimination of flaws and defects in products. [7]. That is why, entrepreneurs began to implement new methods and tools to exclude and remove product defects at the time of design or production [10].

2. APPLICATION OF THE FMEA METHOD IN A SELECTED METALLURGICAL COMPANY

The analysis of potential causes of defects and their consequences was carried out in a selected metallurgical enterprise performing castings of gray and alloy cast iron. After a thorough analysis of the entire course of the process research was carried out together with the information obtained from the warehouse manager and employees. For the research the process was selected from the demand plan through the ordering, delivery and quantity and quality control of the goods.

The course of the research process is initially created in the form of a process map, which is depicted in **Figure 1**. The mapping was initiated from the examination of the process, starting with placing the order through individual stages up to the storage stage. The aim of this process is to manage only the type of outlays such as time, work and information necessary to meet the needs of the recipient. In the next stage, an analysis of offers from suppliers, verification of their structure and placing an order is performed when the offer meets the mandatory criteria. This point is important in the process. The information obtained in the company indicates that a permanent contact with the supplier is necessary to confirm the availability of the goods, in terms of assortment and quantity. The delivery and receipt of the goods takes place after placing the order. The final stage is to perform quality and quantity control of delivery and storage [6].

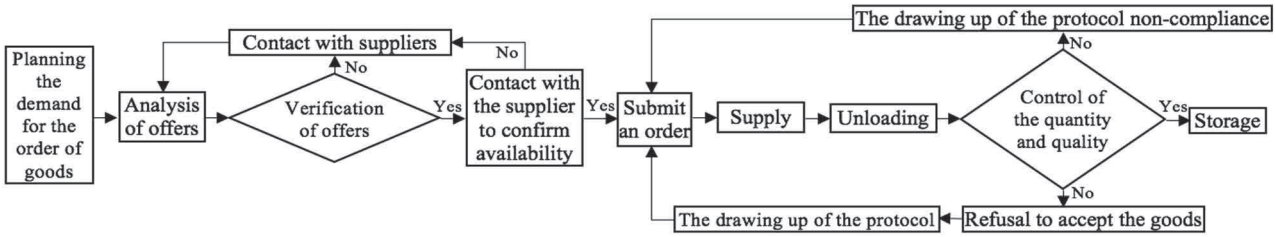

Figure 1 Map of the logistics proces

The next stage of the analysis is to formulate the causes of errors. The ISHIKAWA diagram, which is presented in **Figure 2**, was used to complete this stage. The FMEA analysis determined the significance of faults and errors (Risk Priority Number - RPN) according to formula (1) for the point estimation

$$RPN = Z \cdot R \cdot W \quad (1)$$

where:

Z - Meaning for the customer
R - Probability of a defect
W - Detection of defects

After determining the potential causes of the occurring defects an estimation of the degree of risk for each cause was made. **Table 1** reflects the criteria for estimating *Z, R*, *W* for the described process. In turn the analysis and assessment of the assumed risk together with the results of the verification and optimization of the solutions are presented in **Table 2**.

Table 1 Criteria for estimating the probability of error [2]

Meaning for the customer (*Z*)	Probability of a defect (*R*)	Detection of defects (*W*)
1 slight	1 unlikely	1-2 very high
2-3 low	2-3 low	3-4 high
4-6 moderate	4-6 moderate	5-6 average
7-8 large	7-8 large	7-8 low
9-10 very big	9-10 very big	9-10 very low

Table 2 Systemic FMEA analysis of the process warehouse system of goods

Process	Potential disadvantages	The potential effects of defects	Potential causes of defects	Results before activities				Recommended corrective actions	Results of activities			
				Z	*R*	*W*	***RPN***		*Z*	*R*	*W*	***RPN***
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Planning for demand on top of goods	The order plan is not compliant with the demand plan	- Too small amount of goods makes it impossible to carry out orders - Too many raw materials, the risk of overfilling warehouses	-Incorrect conversion of the number of products, -Erroneous interpretation, haste	1 2	6 8	2 1	**12** **16**	Improvements in the IT system regarding the calculation of demand based on the ordering plan	1 2	2 3	2 1	**4** **6**
2. Analysis of the quantity and quality of offers	No offers, Failing to offer, Incomplete offer, Incorrect interpretation of the offer	-Placing an erroneous order -It is not possible to place an order	-Vendor error -There is no person responsible for receiving and analysing offers -Illegible offer	8 8 6	2 4 8	1 8 10	**16** **256** **480**	Systematic update of the list of preferred suppliers (e.g. company manager)	8 8 6	1 2 6	1 6 6	**8** **96** **216**
3. Contact with the supplier and confirmation of availability	Difficult contact, No confirmation of availability and quantity of products offered	-Lack of timely delivery, incomplete delivery -Failure to complete the full ordering plan	-Unavailability of the person responsible for the coordination of orders, -Failure and errors of the IT system supporting stock levels, -A mistake in the correct order	8 1 10	4 9 2	1 1 1	**32** **9** **20**	Verification of suppliers	8 1 10	2 6 1	1 1 1	**16** **6** **10**
4. Submit an order	A mistake in the order (quantity and range), Error while placing the order into the system	-Lack of timely delivery, incomplete delivery -Failure to complete the full ordering plan	-Incorrect interpretation of the ordering plan Incorrect calculation of the demand -Mistake when placing the order Mistake on delivery -A mistake in transferring orders to be carried out	10 10 10	2 2 1	2 2 1	**40** **40** **10**	Verification and control of the order form before sending (production manager)	10 10 10	1 2 1	2 1 1	**20** **20** **10**
5. Delivery and unloading	Goods damaged during unloading, Delay of delivery	-No possibility of completing the full order plan -Delays in the order -Dedication of additional time for the complaint procedure	-No person authorized to collect the goods Delivery after the deadline -Incorrect securing of goods and conditions during transport	7 7	4 7	1 1	**28** **49**	Introduction of the order tracking system	7 7	2 5	1 1	**14** **35**
6. Quantitative and qualitative control	Shortage of goods, Excess of goods, Lack of quantity control, Lack of quality control of the goods.	- Order delay - Failure to complete the full order plan, - There is not enough space to store the goods.	-Incorrect interpretation of the order, Incorrect order, -A mistake in loading, A mistake at unloading, the workload of people responsible for collecting a goods	8 8	8 8	1 1	**64** **64**	Standardization of control activities, Introducing an additional person supervising and approving the ordering plan	8 8	4 4	1 1	**32** **32**

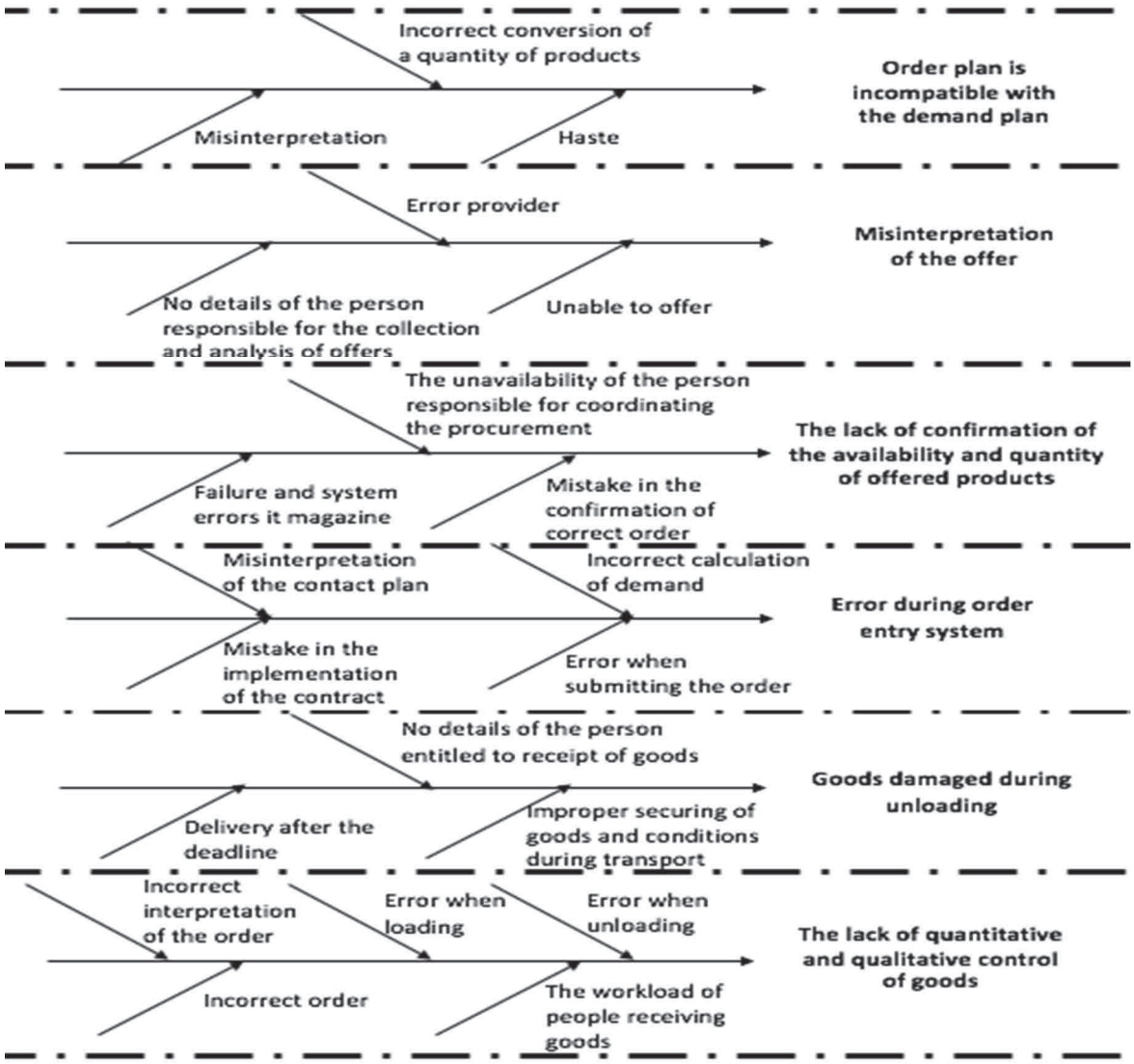

Figure 2 Ishikawa diagrams for potential defects

After the FMEA analysis, the results from the analysis of the "before" and "after" activities are illustrated in **Table 3**.

Table 3 Values of action "before" and "after" using the FMEA method

Defect number	The sum of the RPN (the reasons for the defect)		Accumulated value in %	
	,, before "	,, after "	,, before "	,, after "
1.	28	10	3%	0,8%
2.	752	320	66%	28%
3.	61	32	5%	2,8%
4.	90	50	8%	4,8%
5.	77	49	7%	4,3%
6.	128	64	11%	5,6%

The Pareto diagram (**Figure 3**) was prepared for the data on the basis of **Table 3**. In the chart it can be seen that the errors appearing were arranged in descending order of the value columns. Such order allows to illustrate which problems should be dealt with first. Visual illustration of important issues helps to focus on eliminating the factors that cause a significant part of the problems.

Legend:

1. The order plan is not compliant with the demand plan.
2. Incorrect interpretation of the offer.
3. Lack of confirmation of availability and quantity of offered products.
4. Error during placing the order into the system.
5. Goods damaged during unloading.
6. Lack of quantitative and qualitative control of the goods.

Figure 3 A summary of activities before and after the FMEA analysis

3. CONCLUSIONS

Carried analysis yielded effective results. Six main defects in the process were identified of which 30% are mainly dangerous defects for the process. By using the Ishikawa diagrams, the causes of the six defects were identified and then the countermeasures were clearly defined in order to eliminate them. The most significant improvement is the order plan that is not in line with the demand plan. Its error rate has been improved by 38%. Another improved operation is greater quantity and quality control of goods by 5.4%.

The use of the FMEA method in the enterprise allowed mainly for: recognition of the causes and effects of potential discrepancies in the analyzed process, increasing the efficiency and quality of the ordering process and the delivery of goods, creating an emergency plan in case of non-compliance or mistakes in the process, a certificate that the products will be delivered to the recipient exactly on time, in the right quantity and in the right place.

The analysis of the causes of defects and their effects in the storage system was the first of all started by defining potential incompatibilities for a single stage of the process and their consequences. In addition, it was assumed that general activities except for the analyzed process are carried out according to the standard. Describing the consequences of non-compliance the situation was identified which would stop the next stage of the process as well as effects for the client.

Then using the **Table 1** the significance (Z), occurrence (R) and detection (W) of potential discrepancies in the process were made. The problem was revealed when assessing the defect occurrence criterion considering that the company does not register the incompatibility of the defect (frequency of occurrence). Subsequently, according to the risk estimation formula (1) the number of its risk values (RPN) was calculated. It has been assumed that the most significant defects are those whose level of risk (RPN) is greater than 20. In this area 6 dangerous defects were identified as a result of an inadequate process of completing the order at source for delivery to the company's warehouse. The disadvantages include: the order plan is inconsistent with the RPN demand plan = 28 the indicator has been reduced to 10; incorrect interpretation of the RPN offer = 752 the indicator has been minimized to 320; lack of confirmation of the availability and quantity of products offered RPN = 61 the index has been minimized to 32; error during placing the order into the RPN system = 90 the indicator has been minimized to 50; goods damaged during unloading RPN = 77 the indicator was minimized to 49; lack of quantitative and qualitative control of the goods RPN = 128 the indicator has been minimized to 64.

Then corrective actions were recommended which enabled the reduction of this index by reducing the occurrence of non-conformities and increasing the detection of the defect. The final stage was the review and standardization of the works that should be performed: cyclically, controlling the applied corrective actions verifying their effect, after every major change in the process.

Regular use of the FMEA method will enable metallurgical enterprises in the future to avoid the effects of defects, errors in the fundamental process of planning and storage of goods from the perspective of the operations of the plants. As one of many quality management methods, FMEA method analysis in logistics processes brings significant economic effects related also to the increase of clients' trust.

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