THE USE OF THE FMEA METHOD FOR QUALITATIVE ANALYSIS OF STEEL BARS

Manuela INGALDI[1], Szymon T.DZIUBA[2]

[1]Czestochowa University of Technology, Faculty of Management, al. Armii Krajowej 19b p.309z, 42-200 Czestochowa, Poland, manuela@gazeta.pl

[2]Wroclaw University of Economics, Faculty of Engineering and Economics, ul. Komandorska 118-120, 53-345 Wroclaw, Poland, szymon.dziuba@ue.wroc.pl

Abstract

One of the most frequently used methods of quality management in manufacturing and industrial enterprises is the FMEA method. The FMEA (i.e. Failure mode and effects analysis) is a method of systematic prevention of defects. It allows to specify actions to minimize the risk of defects' occurrence. The FMEA is most often used wherever products with a high degree of complexity are manufactured or when the production process is a multi-stage process or when in the production process many people take part. Due to its universal character it is used in mass production, unit production, especially industrial production. The literature states that this method can be widely used in the metallurgical industry. While conducting the FMEA analysis, the knowledge and experience of employees working in higher positions, technologists, employees of quality departments, but also directly production employees can be used, but also it can be treated as a motivation tool for them. The purpose of the paper was to analyze quality of steel bars which are produced by one of the steelwork in Poland. The FMEA method was used for this analysis. The cause and effect are presented for each production problem. After calculating the risk priority number, corrective actions were proposed. After the introduction of these corrective actions, the risk priority number was re-calculated to see if these actions have caused the intended effect.

Keywords: Quality, FMEA, risk priority number, steel bars

1. INTRODUCTION

One of the most popular methods of quality management in Polish industrial enterprises is failure mode and effects analysis (FMEA). The method, with its analysis of the risk of inconsistencies in the product or process, helps eliminate the defects before they occur. This prevents from expenses connected with e.g. repairing products that have to be incurred by the enterprise.

The FMEA method is a widely used quality management method and is especially effective in the case of the analysis of complex products or processes. This analysis can concern an individual part or subassembly or the entire product or part of the process (e.g. one operation) or the entire technological process.

The method is especially useful during the design stage, where the risk is evaluated for alternative solutions. Weaknesses of an entire process or a product are evaluated and the suggestions for facilitation are made. A particular focus is on inconsistencies and defects which occur the most or have the biggest effect on the entire process [1].

FMEA allows for identification of the activities that minimize the risk of defects. FMEA is most often used where products with high level of complexity are manufactured and many people take part in the manufacturing process. Due to its universal character, the method is used in serial production, unit production and services and administration [2-3].

The aim of the paper was to analyze quality of steel bars produced by one of the steelworks in Poland. The analysis was based on the FMEA method. One the risk priority number was computed; the corrective measures were proposed. After implementation of these activities, the risk priority number was computed again in order to verify whether the proposed measures produced the expected effects.

2. METHODOLOGY

FMEA is a technique that allows for identifications of defects and helps eliminate them. FMEA analysis is used to identify and evaluate risks of occurrence of potential defects in individual parts of the product or in the manufacturing process as well as the effects of these problems [4]. The method consists in analytical determination of cause-and-effect relationships between potential product defects and taking into consideration the criticality factor (risk) [5].

According to the literature, there are a number of objectives to conduct FMEA analysis in the entities [6-9]:

- consistent and regular elimination of the defects (weaknesses) in products (product structure) or production process (e.g. processing) through recognition of actual causes of their generation and using adequate means of prevention,
- avoiding occurrence of previously recognized as well as unknown defects in new products and processes by using the knowledge and experiences from the previous analyses,
- identification of the activities which would eliminate or at least limit the likelihood of potential defects,
- documenting the process,
- analyses of the product or process and, based on the results, implementation of corrections or new solutions which would effectively eliminate the source of defects,
- creating of the database in the form of corrective measures,
- increasingly high product complexity and, consequently, the danger of greater number of defects during production and greater amount of complaints.

Therefore, it can be concluded that the FMEA method allows for introduction of new solutions, more economical production processes and saving not only materials and used parts but first and foremost, save the previous time.

It should be noted that in general, there are two types of FMEA analysis [4,10,11]:

- Project FMEA - it allows for doing things right for the first time. This analysis is aimed at identification of factors that are likely to lead to potential disturbances in manufacturing processes is conducted in this case. Project FMEA is used mainly at initial stages of designing of any technological processes before the serial production is started i.e. production planning, and during serial production in order to improve processes which are unsteady or do not ensure required performance.
- Process FMEA - it allows for identification of the problems and disturbances which can be observed during performance of planned processes, oriented mainly towards optimization and reliability of the product. This analysis allows for obtaining information about strengths and weaknesses of the product. Apart from these preventive measures, this FMEA helps determine the actions which allow for making decisions if a product already left the enterprise i.e. during transport or maintenance. The analysis may concern not only the entire product or its assemblies but also subassemblies and, in exceptional cases, only some parts. Conducting the FMEA analysis is especially recommended for implementation of entirely new products, parts, materials and technologies if huge risk is generated for human safety or the environment, if product failure (or defect) occurs or if the product is used in particularly critical and difficult conditions.

The literature emphasizes the following basic benefits of using FMEA [12-14]:

- employee integration through solving problems in teams,
- using employee knowledge and consequently using better solutions for manufacturing products and providing services,
- important reduction in the level of costs while increasing quality,
- improved efficiency of the analyzed process,
- improvement in opportunities to meet customer expectations and the respective customer satisfaction,
- increased customer satisfaction,
- increase in efficiency of activities oriented at improved quality, especially prevention of defects,
- improved product reliability,
- facilitation of information flow in the organization,
- development of data bank concerning the problems, their causes and methods to correct them etc.

An FMEA analysis for round bars manufactured in a rolling plant of a steelworks was performed in this paper. The examinations were conducted in the period from September to December 2017. The FMEA analysis took into consideration 11 most frequent defects of steel round bars. Causes and effects were determined for all defects. Three priority numbers were determined: severity (S), probability (P) and detection (D). These numbers were used to compute risk priority number (RPN). Next, the corrective measures were proposed. After implementation of the corrective measures, the RPN was computed again.

The steelworks X is one of the biggest suppliers and steel importers in the European market, active in each link of the steel supply chain. The enterprise has the plants which process scrap metals, steelworks, production plants and warehouses all over the world. The Bar Rolling Plant, opened in September 1999 by an Italian company, is the most modern production plant of this kind in the Central Europe. The investment allowed for offering high-quality products that correspond to European standards.

From steel, commercial activity, financing trade, distribution through to warehousing, the steelworks processes over million tons of steel products a year. With branches in 12 countries and additionally partnership commercial offices all over the world, the company has long-term commercial contacts with world producers, professional knowledge and resources that allow for supplies of any types of steel products in order to meet customers' needs in all places of the world.

3. RESULTS

Table 1 presents the results of the FMEA analyses performed for steel bars produced by the company.

In order to sum up the analysis, a graphical interpretation of the results was developed as presented in **Figure 1**. A critical value of RPN=60 was adopted due to the fact that they are used for steel structures as these structures require behaving adequate parameters of materials used for their creation.

All the proposed corrective measures were implemented. After the implementation and renewed computation, the implementation effects were evaluated. RPN was reduced in all cases.

The highest RPN number was observed in the case of N2 defect (teeming lap). They were caused by mechanical damages. For this defect, corrective measures in the form of the rolling process analysis were proposed. The highest increase in the value of RPN was also found for this defect.

Table 1 FMEA for round bars [own study]

No	Potential defect	Potential effects	Potential causes	Before corrective measures				Corrective measures	After corrective measures			
				S	P	D	RPN		S	P	D	RPN
N1	Internal cracking	Internal cracking	Improper alloy composition	3	3	4	36	Analysis of proportions and amounts of components	3	2	2	12
N2	Teeming lap		Mechanical defects	7	5	3	105	Analysis of the rolling process	7	4	1	28
N3	Excessive thickness of decarburized layer		Improper alloy composition	10	4	1	40	Analysis of the rolling and cooling process	10	2	1	20
N4	Coarse-grained steel		Improper alloy composition	6	2	3	36	Analysis of proportions and amounts of components	6	2	2	24
N5	Oval		Mechanical defects	4	3	4	48	Periodical calibration and maintenance	4	3	3	36
N6	Scales	In the present state, bar is unable to be used. Material is moved to the repeated melting	Improper alloy composition	6	2	3	36	Analysis of the rolling process	6	2	2	24
N7	Non-metallic inclusions		Improper alloy composition	4	4	6	96	Analysis of proportions and amounts of components	4	3	4	48
N8	Non-homogeneous structure over the entire cross-section		Mechanical defects	6	3	3	54	Analysis of the rolling process	6	2	1	12
N9	Microshrinkage		Improper alloy composition	6	3	3	54	Analysis of the rolling process	6	2	2	24
N10	Hot tears		Mechanical defects	8	3	3	72	Analysis of the rolling process	8	2	2	32
N11	Lapping	Material is redefined to the second grade.	Mechanical defects	3	5	1	15	Analysis of the rolling process	3	2	1	6

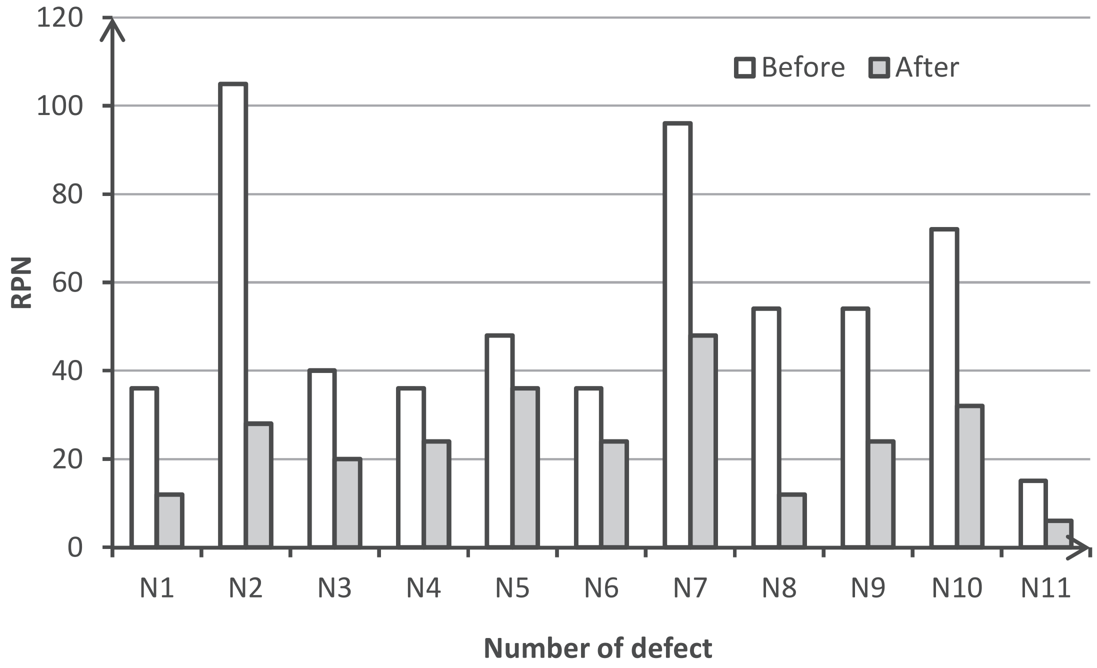

Figure 1 Comparison of RPN before and after corrective measures were implemented [own study]

Another defect that involved high risk was N7, metallic inclusions, caused by improper alloy composition. In this case, it is necessary to analyze proportions and amount of components.

The last defect which exceeded a critical RPN value is N10: hot tears, caused mechanical damages. The analysis of the rolling process was also proposed in this case.

The enumerated most important defects make it impossible or substantially limit product function. Therefore, it is important to reduce the involved risk.

4. CONCLUSION

An FMEA analysis of steel round bars produced by one of the steelworks in Poland was presented in this paper. The examinations were conducted in the period from September to December 2017. The FMEA analysis took into consideration 11 most frequent defects of steel round bars. The critical level was priority number of 60.

It turned out that the most serious defects of steel round bars include teeming lap, metallic inclusions and hot tears. Corrective activities were proposed for all the defects, followed by the FMEA analysis which confirmed the necessity and efficiency of these activities.

The analysis demonstrated that FMEA can be successfully used in the foundry sector. Although the analysis can be time-consuming, it is not as difficult as it may seem to be. Therefore, the paper can be used as a recommendation for a broader use of the method.

REFERENCES

[1] INGALDI, M. Metoda FMEA jako instrument zarządzania jakością. In Paliszkiewicz J., Ingaldi M. (Ed.) *Teoria i praktyka w zarządzaniu produkcją i usługami.* Czestochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Jakości i Produkcji, 2016, pp. 9-22.

[2] KARDAS, E., BROZOVA, S., PUSTEJOVSKA, P., JURSOVA, S. The evaluation of efficiency of the use of machine working time in the industrial company - case study. *Management Systems in Production Engineering,* 2017, vol. 25, no. 4, pp. 241-245.

[3] YANG, C. S., ZOU, Y. N., LAI, P. H., JIANG, N. Data mining-based methods for fault isolation with validated FMEA model ranking. *Applied Intelligence*, 2015, vol. 43, no. 4, pp. 913-923.

[4] PRIBULOVA, A., BABIC, J., BARICOVA, D. Influence of Hadfield's steel chemical composition on its mechanical properties. *Chemicke Listy*, 2011, vol. 105, suplement 4, special issue, pp. 430-432.

[5] LOLLI, F., ISHIZAKA, A., ISHIZAKA, A., GAMBERINI, R., RIMINI, B., MESSORI, M. FlowSort-GDSS - A novel group multi-criteria decision support system for sorting problems with application to FMEA. *Expert Systems with Applications*, 2015, vol. 42, no. 17-18, pp. 6342-6349.

[6] CZAJKOWSKA, A. Identification and analysis of non-conformities in production of construction materials with the example of hot-rolled sheet metal. In *METAL 2015: 24th International Conference on Metallurgy and Materials*. Ostrava: Tanger, 2015, pp. 1878-1883.

[7] KOTUS, M., HOLOTA, T., PAULICEK, T., PETRIK, M., SKLENAR, M. Quality and Reliability of Manufacturing Process in Automation of Die-Casting. *Materials, Technologies and Quality Assurance. Book Series: Advanced Materials Research*, 2013, vol. 801, pp. 103-107.

[8] SU, C. T., LIN, H. C., TENG, P. W., YANG, T. Improving the reliability of electronic paper display using FMEA and Taguchi methods: A case study. *Microelectronics Reliability*, 2014, vol. 54, no. 6-7, pp. 1369-1377.

[9] RYCHŁY-LIPIŃSKA, A. FMEA - analiza rodzajów błędów oraz ich skutków. *Zeszyty Naukowe Wydziału Nauk Ekonomicznych Politechniki Koszalińskiej*, 2007, no 11, pp.47-59.

[10] KRYNKE, M., KNOP, K., MIELCZAREK, K. An identification of variables that influences on the manufactured products quality. *Production Engineering Archives*, 2014 vol. 4, no. 3, pp. 22-25.

[11] DULSKA, A., STUDNICKI, A., SZAJNAR, J. Reinforcing cast iron with composite insert. *Archives of Metallurgy and Materials*, 2017, vol. 62, no. 1, pp. 355-357.

[12] SKOTNICKA-ZASADZIEŃ, B. Analiza efektywności zastosowania metody FMEA w małym przedsiębiorstwie przemysłowym. *Systemy Wspomagania w inżynierii produkcji*, 2012, vol. 2, no 2, pp. 142-153.

[13] ZHURAVSKAYA, M., MOROZOVA, E., ANASHKINA, N., INGALDI, M. Toyota-Oriented Technologies as Ecological Management Tools for Transport Enterprises. *Polish Journal of Management Studies*, 2016, vol.13, no. 2, pp. 192-203.

[14] KARDAS, E. The analysis of non-conformances of metal impeller using selected quality instruments. In *METAL 2015: 24th International Conference on Metallurgy and Materials*. Ostrava: Tanger, 2015, pp. 1970-1975.