ANALYSIS OF THE CAUSES AFFECTING THE PRODUCTION QUALITY OF THE ENGINEERING COMPANY

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Abstract

For small and medium-sized companies operating in engineering, producing quality and non-defective products is indispensable. In order to ensure the occurrence of such products, the management must regularly monitor its production process and set preventive measures to prevent problems. Preventive measures should focus on the causes of problems. Constructing a C-E diagram allows identifying the whole range of possible causes of a problem. These causes can then be traced back in the production process and focus on those with the most occurrences. Using the FMEA method, it is possible to identify the level of risk of individual causes and propose a procedure to prevent their occurrence. In the researched company producing sorting machines and lines, it was possible to identify many causes of insufficient surface treatment of products. Based on their occurrence in the last two years, the FMEA pointed out the high risk of lighting distribution in the hall and inconsistent human work.

Keywords: Quality, Production, C-E diagram, FMEA

1. INTRODUCTION

An efficient production process combined with adequate quality control has become the basis of manufacturing enterprises [1]. Although quality management became popular in the 1980s and 1990s, 21st-century businesses still need help with the concept. Product recalls and customer complaints are serious quality management problems that have resulted in significant profit losses due to increased costs of poor quality [2]. Product quality and delivery reliability are critical success factors in the small and medium-sized manufacturing industry. Emphasis on sustainable production requires efficient use of resources, processes and production systems. In recent years, in the field of quality control, many tools have been used for monitoring and evaluating processes in order to achieve the required product quality. Production quality for modern manufacturing industries emphasises zero defects. In this case, it is possible to perceive a strong interaction between production logistics, quality and maintenance functions [3].

Most organisations use quality tools for various purposes related to quality control and assurance. Specific quality tools are available for certain areas and problems. There are also quality tools that can be used across multiple areas [4]. A significant part of the methods relies on the expert approach of experts and people encountering the process regularly. However, we can already observe that some solutions are also based on more complex calculations and simulations focused on the expected development. The author's contribution [5] presents a model of low-quality cost analysis and calculation using a software tool. The production process is observed in terms of costs and low quality of its organisation. The use of simulation software allows for the incorporation of uncertainty in the input variables. In conclusion, they state the effective use of simulation software tools in quality management, but also with identified limits. In the preparatory phase of the simulation, it is still possible to observe the irreplaceable role of experts who know the examined processes [5]. On the other side, for example, is Failure Mode and Effect Analysis (FMEA). It is an analytical technique that relies on human experience to identify the likely failure mode of a product or process and plan to eliminate those failures [6].

The company subjected to quality control in this paper shows a high product return rate. The company manufactures large vibrating machines for the mining industry. Due to the product's exposure to vibrations during a significant part of its life cycle, its faultlessness is an inherent condition of customers. In addition, the company's customers are large international companies operating in the mining industry, which also requires one hundred per cent flexibility towards their requirements. Based on complaints and justifications for product returns, a problem was identified with the surface treatment of the metal parts of the machines, which caused poor resistance and adhesion of the joints. Little blank spaces that arise in connection with vibrations cause severe damage over time.

This article aims to analyse the causes of the given problem and define the most severe causes of product complaints. One of the seven essential quality tools, the C-E diagram, is used to search for causes. A structured search for the causes of the problem in terms of C-E diagnostics and subsequent evaluation of the riskiest causes is essential for the company so that the company can proceed to their elimination as soon as possible.

2. METHODS

Seven essential quality tools are used in organisations. These tools can provide much information about problems in an organisation. These seven tools are: histogram, cause-and-effect (C-E) diagram, Pareto diagram, correlation diagram, control diagram, data stratification, and brainstorming. A C-E diagram is a simple graphical tool for understanding the causes that cause quality defects and is used to analyse the relationship between a problem and all possible causes. The diagram clearly illustrates the relationships between a problem identified in a manufacturing process or product and its potential causes. C-E diagrams began to gain popularity in the 1960s. The pioneer was Kaoru Ishikawa, a prominent figure in quality management. That is why C-E diagrams are also called Ishikawa diagrams [4].

The process of creating a C-E diagram can be defined by the following steps [7]:

- clear definition of the problem,
- defining the main groups influencing the problem,
- identifying the causes of the problem, which will be divided into the main groups of the diagram,
- analysis of the diagram and causes.

The C-E diagram is divided into main groups, organised according to Ishikawa's principle of sequence and continuity of the process in time: Materials, Methods, Technologies, Measurements, Men, and Environment. C-E diagnostics is the basis for the creation of FMEA [7].

FMEA began to be used in engineering manufacturing in the US aerospace industry in the 1950s. Initially, it was used to solve problems with the quality and reliability of military products. With the increasing emphasis on quality, the FMEA method has also established itself in other industries. It is an effective tool for analysing and improving system quality and reliability in various industrial sectors. FMEA can independently analyse product design, production, and service stages to identify and evaluate potential failure modes at each stage in advance so that improvement measures can be quickly proposed [8].

The role of FMEA is to recognise and evaluate potential failure and its effects. Then, identify activities that could eliminate or reduce the possibility of potential failures and document the process. The FMEA execution consists of selecting processes or functions of the system for which it is necessary to determine failure modes and evaluate their severity S. Subsequently, possible causes of failures in the system are sought. The realtime occurrence of failure O is evaluated. Then, the options and approaches for failure detection are presented, and their ability to detect fault D is evaluated. By multiplying the severity, the probability of occurrence and the possibility of detecting the fault, the RPN risk priority number is calculated, which we want to keep as low as possible. The last step is to design and implement a measure to prevent another failure. In this step, it is possible to recalculate the RPN [6].

The conventional procedure for classifying the severity (S) of the fault effect is rated on a scale from "1", no effect to "10", dangerous without warning. Probability of Occurrence (O) should be ranked on a scale from '1' as unlikely failure to '10' as inevitable failure. Like severity and occurrence, detectability is ranked on a scale from "1" that controls will detect to "10" as an undetectable failure [9].

3. RESULTS AND DISCUSSION

The quality control tools and methods described in the previous chapter were applied to the custom production of an engineering company. Among other orders, the company mainly produces vibrating sorters used in the mining industry. A vibrating sorter is a device used in the initial processing of raw materials in mining or processing operations. Its main task is the separation of different fractions of the given raw material. For separation, it uses the principle of vibration and falling of the raw material. It follows that during the life cycle, the device is exposed to relatively strong vibrations. Therefore, its construction must be flawless, and there must be no deviations. Exposure to vibrations for a long time, even in the case of a deviation in micrometre dimensions, can cause severe damage to the machine.

While monitoring its production process, the company noticed many semi-finished products returned to production, which the chief controller attributed to insufficient surface treatment. Subsequently, the sales director looked for the same problem in the complaint files. Most of the complaints were also tied to a problem with the surface of the device. The company needs to identify the most severe cause of the insufficient surface treatment of the product soon.

Before proceeding to the identification of the most severe cause, it is necessary to know the database of the causes of the problem. C-E diagnostics will be used to find the causes. The diagnosis of the problem was carried out with the participation of the chief controller, the production director, supervisors from both shifts and two external consultants. Those present had to agree on the unequivocal determination of the possible cause. The identification of the causes was carried out for each internal complaint, and the frequency of occurrence of the causes was monitored. The list of causes and their frequency is in **Table 1**.

Table 1 List of causes of insufficient surface treatment

Cause	Frequency of occurrence	Cause	Frequency of occurrence
1. Incorrect weighing of paint and hardener	29	9. Improper application of coatings	8
2. Short interval between coats	103	10. Failure to measure the thickness of coatings	113
3. Poor lighting	127	11. Low temperature	69
4. Failure to measure the surface after blasting	58	12. Absence of extraction of the blasting medium	92
5. Uncalibrated gauges	11	13. Inconsistency of workers	65
6. Environment polluted by medium from blasting	40	14. Inappropriate concentration of diluter in the paint	34
7. Greased surfaces	16	15. Inoperative blasting device	58
8. Overloading of workers	118		

The frequency of occurrence in **Table 1** means the occurrence of an internal or external complaint, so it does not apply to all manufactured products but only to those where a defect was identified.

Of the causes listed in **Table 1**, the most severe losses for the company were brought about by a combination of non-functioning blasting equipment and environmental pollution from blasting media. The article's authors [10] have already addressed these causes, which simultaneously caused the prolongation of the entire production process. By inserting a new device and reorganising the production process, they could capture the blast medium, ensure the reliability of the production operation and shorten the production time [10].

For the C-E diagnosis, the collective established four subject categories: Methods, Measurement, Environment and People. The C-E diagram in **Figure 1** is the result of the diagnosis.

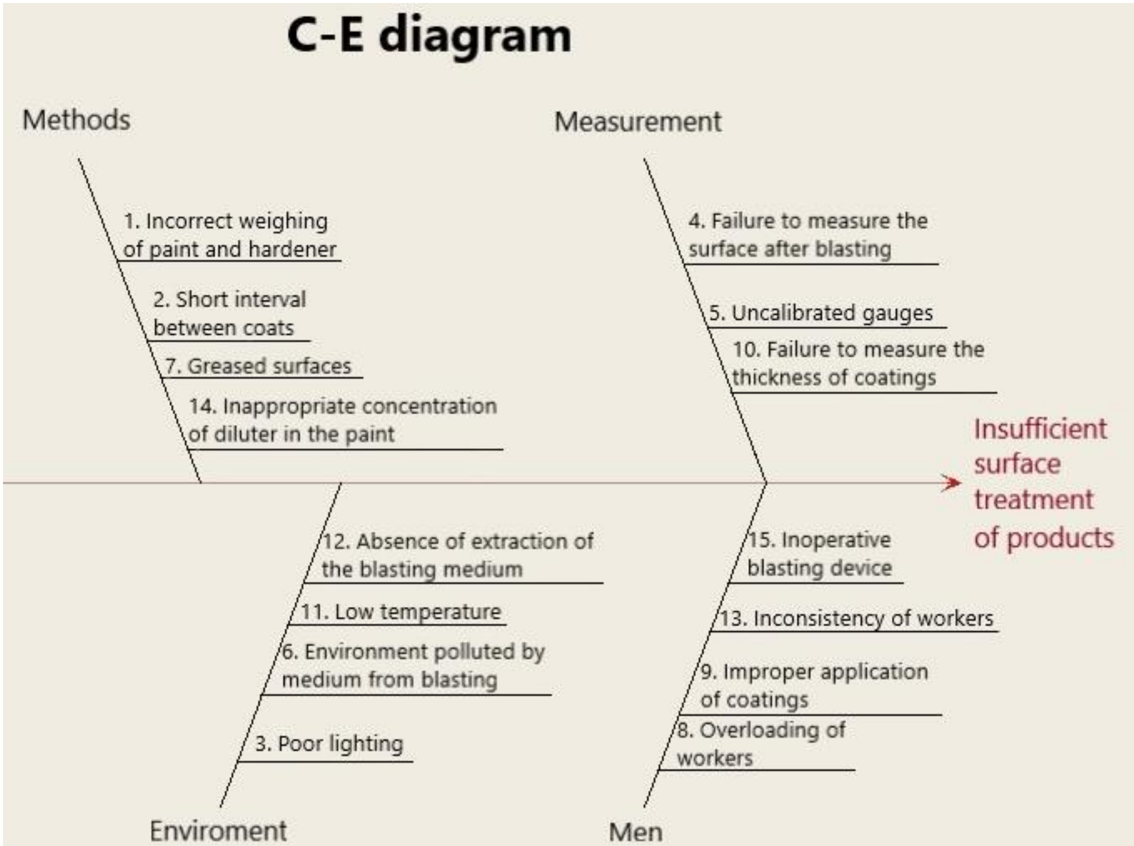

Figure 1 C-E diagram of insufficient surface treatment

The cause of worker inconsistency is a human factor failure other than those specified in the C-E diagram. Incorrect weighting of paint and hardener and low temperature also cause serious consequences. The next step is to determine the most severe cause from the diagram so the company can determine its priorities in dealing with the causes. The team used the FMEA method. To reduce labour and the burden on the team, they decided to apply the FMEA method to the incorrect weighing of paint and hardener and low temperature due to their severe consequences and the overloading of workers, failure to measure the thickness of the coating and poor lighting due to their frequent occurrence.

The purpose of applying the FMEA method is a closer examination of the causes, their manifestations, impacts and an effort to find the root cause. The FMEA method applied in this analysis, in addition to identifying the riskiest causes, also lists recommended actions to mitigate the calculated figure. The data required for RPN recalculation have yet to be identified. Therefore, RPN recalculation still needs to be carried out. The resulting FMEA table is **Table 2**.

Table 2 FMEA process

Subject of analysis	Potential Failure Mode	Potential Effect of Failure	S	Potential Causes	O	Current Control	D	RPN	Recommended Actions
1. Incorrect weighing of paint and hardener	Colour precipitation	Deterioration of colour	6	Incorrectly calibrated scale, inconsistency of workers, inappropriate mixing of agents	3	Agents concentration scheme for coatings	6	108	Regular calibration check, agent mixing training of workers
	Extended or shortened drying	Inappropriate coating	7					126	
		Prolonging the process	6					108	
11. Low temperature	Different surface thicknesses	Lack of adhesion after assembly	9	Different extensibility of the material	3	Placement of heaters	2	54	Insulation of the workplace, provision of a heating system
	Deformation of machines	Instant complaining	7	Wrong solution for heating the workplace	2		2	28	
	Inaccurate measurements	Parts reworking	7	Inaccurate calibration at low temperature	5		4	**140**	
8. Overloading of workers	Different surface thicknesses	Lack of adhesion after assembly	9	Lack of professional staff, unbalanced planning	4	Visual control, dispatch control	2	72	Hiring workers, lockup a plan before its implementation
	Untreated surfaces	Polluted and greasy spots	4					32	
10. Failure to measure the thickness of coatings	Paint falling off	Lack of adhesion after assembly	9	Thick coating	6	Occasional inspection by the controller	3	**162**	Increasing the consistency of measurements and the frequency of checks
	Insufficient anti-corrosion protection	Corrosion of product parts	10	Thin coating	3			90	
3. Poor lighting	Different surface thicknesses	Lack of adhesion after assembly	9	Outdated lighting system, low light intensity, inappropriate layout of lamps	7	Multiple check, LED floor lamps	3	**189**	Replacement of the lighting system
	Untreated surfaces	Polluted and greasy spots	4					84	

According to the RPN in **Table 2**, the riskiest for the company is the state of lighting in the workplace, with a value of 189 and its inability to maintain the required temperature, suitable for carrying out operations, with a value of 140. The company should soon find means to reconstruct the halls in the area to remove critical causes of the problem with the surface treatment of products and the resulting complaints.

However, the second most significant value of RPN is related to errors during coating thickness measurement. There is often a thick coating, the worst consequence of which can even be the non-functionality of the machine. The thick coating tends to fall off due to constant vibrations and thus creates small spaces that affect the machine's stability. Further analysis of quality should deal in depth with the causes of the thick coating so that the company can avoid this relatively frequent failure.

FMEA results also indicate a high risk of errors caused by the human factor. In the background of the majority of potential causes, it is possible to deduce the employee's misconduct. The company should devote itself to thoroughly training its workers and their control.

4. CONCLUSION

The company, struggling with a high number of product complaints, resorted to diagnosing the causes of the main problem with the surface treatment of the products. Many tools are currently used for quality control in companies. The presented analysis proves that even the most basic are still relevant nowadays.

Using C-E diagnostics, a team of experts from the company and representatives of the analysis team were able to identify 15 causes causing a problem with the quality of the surface treatment. During the analysis, the causes associated with the blasting medium were already eliminated by the reorganisation and modernisation of one of the production operations. Subsequently, the experts subjected the remaining two serious causes and the three most frequently occurring causes to FMEA analysis.

The result of the analysis is a clear risk resulting from the inappropriate condition of the halls in which the production process is located. The halls need immediate intervention and modification of the lighting system and improve the maintenance of the required temperature. In addition to these problems, it is possible to observe the frequent appearance of thick coating on parts of the products, which can lead to severe problems during their use. Behind this and other causes, it is possible to deduce the presence of human factor failure. This fact should be subjected to further analysis in the field of quality control in the company.

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