QUALITY ENGINEERING TOOLS IN PRODUCTION PROCESS IMPROVEMENT

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Abstract: This article highlights the important role of quality engineering tools in process improvement. As an example, paper production has been selected for analysis. In order to improve the situation, two tools were proposed. In the first place, the ABC method was used to identify the defects that generate the highest costs in the manufacturing process. The Ishikawa Diagram was used for these defects, which allowed to determine the causes of critical defects occurring in the analyzed manufacturing process.

Keywords: quality, tools, engineering, Pareto analysis, Ishikawa diagram, continuous improvement.

1 Introduction

Quality engineering allows to analyze the manufacturing processes to maximize the quality of these processes and the products that result from them. In order to gain competitive advantage, companies use different approaches and management concepts. Some of them have focused their attention on continuous improvement as the basis of many concepts, including quality management or total quality management. Quality management in the enterprise will not bring the expected results without the practical application of methods and tools to improve company's processes and products [4]. The choice of these instruments should not be reflexive, but rather depend on the situation with which we are dealing. The aim of this paper is to present the possibility of improving the production process in company X using selected quality engineering tools. In order to improve current situation in the production process of the selected company the ABC method and the cause-effect diagram were proposed.

2 Using quality tools in paper production process

Analyzed company X produces paper directly from wood which may make the production system complex and time consuming. It consists of seven processes. It starts with the proper processing of wood, its grinding and transformation into pulp. There are then processes to convert the pre-paper pulp into ready-made office paper bundles. Production ends with receiving a paper office bale from the paper machine, which is then transferred to further processing (cutting) or to the warehouse. In the discussed process, defects were identified at subsequent stages of the manufacturing process. The defects at the level of individual operations are shown in Table 1.

Table 1. Defects occurring at the level of particular operations of the wood production process

PROCESS		OPERATION		DEFECT	
A	Sorting of wood	A1	Weighing of the wood	A1	Maximum permissible wood weight exceeded
		A2	Measuring the diameter of a tree	A2	Too little wood diameter
B	Removal of bark from wood rollers	B1	Mechanical removal of bark from wood rollers	B1	Not properly cleaned wood rollers
C	Cutting rollers on chips	C1	Mechanical cutting of wood trunks on wood chips	C1	Too big chips
		C2	Sorting of wood chips in sorting sieves	C2	Not properly sorter chips
D	Spinning on paper pulp	D1	Mechanical milling of wood chips using water	D1	Too thick paper pulp
		D2	Mass heating and dissolving	D2	Incorrect mass consistency
E	Bleaching process	E1	Bleaching with bleach	E1	Inadequately bleached mass
F	Machining process in paper machine	F1	Formation	F1	Insufficiently filled form
		F2	Ironing the ribbon	F2	Too thick ribbon
		F3	Drying	F3	Wet paper ribbon
G	Bale forming process	G1	Cut and wind the paper ribbon on the roll	G1	Inappropriate cutting of paper

Source: [2]

A Pareto analysis was used as a tool to prioritize defects in paper production, the use of which is described in the next chapter.

2.1 Application of Pareto analysis

Pareto analysis uses the empirically established regularity that approximately 70% -80% of the effects are caused by about 20% -30% of the causes. This rule, known as 20-80 rule or Pareto rule, was discovered by the Italian economist and sociologist Vilfredo Pareto (1848-1923). As part of his study, he analyzed the distribution of income in Italian society [6]. The Pareto Diagram represents in decreasing order the relative contribution of each factor (cause) to the total effect (on the occurrence of the problem). It enable to focus on corrective or improvement actions for the most important reasons. The Pareto diagram is often supplemented by the Lorenz graph, which presents the dependencies analyzed in the cumulative diagram [1]. According to the Pareto concept all elements of the studied area are divided into three groups A, B, C [6]. Accordingly, Pareto analysis is also called ABC analysis. The characteristics of each group are as follows [5]:

1. Group A - the most important elements belong to the group. By taking about 5% -20% of the total number of elements, they contribute to about 75% -80% of the value of the analyzed phenomenon. The actions taken should focus mainly on factors in this group. Such activities bring the greatest benefits.
2. Group B – elements of medium significance belong to the group. By taking about 20% -30% of the total number of elements, they contribute to about 10% -20% of the value of the analyzed phenomenon. The actions taken on the elements of this group will result in much less effect than the actions taken on the elements from group A.

3. Group C - the elements of the least importance. By taking about 50% -75% of the total number of elements, they contribute only 5% -10% of the value of the analyzed phenomenon. Actions taken in relation to elements belonging to this group may often not be economically justified.

In the analyzed example, it was decided to get to know the defects generating the highest costs in the paper production process. For this purpose, the ABC analysis was used. Firstly, data were collected on the number of defects occurring in particular operations of the production process and generated costs related to their correction. Based on the collected data, the total and cumulative cost of the correction was calculated for each defect. This allowed us to classify the individual defects into a particular group to determine the defects that are the most costly for the company X. To attribute defects to individual groups, it was assumed that:

- Group A generates 80% of the total cost of the correction, i.e. 1 248 470 PLN x 80% = 998 776 PLN,
- Group B generates together with group A 95% of the total cost of the correction, i.e. 1 248 470 PLN x 95% = 1 186 046. 5, PLN
- Group C is the remaining defects.

The results of the ABC analysis for the identified defects in the paper production process at Company X are shown in Table 2.

Table 2. Classification of defects using ABC analysis

	Defect	Number of occurrences	Unit cost of correction [PLN]	Total cost of correction [PLN]	Cumulative cost of correction [PLN]	Group
F2	Too thick ribbon	68	3100	210800	210800	A
C2	Not properly sorter chips	56	3000	168000	378800	A
D2	Incorrect mass consistency	27	4850	130950	509750	A
G1	Inappropriate cutting of paper	39	3000	117000	626750	A
F1	Insufficiently filled form	40	2900	116000	742750	A
B1	Not properly cleaned wood rollers	50	2200	110000	852750	A
E1	Inadequately bleached mass	29	3780	109620	962370	A
D1	Too thick paper pulp	20	4600	92000	1054370	B
C1	Too big chips	25	3600	90000	1144370	B
F3	Wet paper ribbon	12	5000	60000	1204370	C
A1	Maximum permissible wood weight exceeded	25	1500	37500	1241870	C
A2	Too little wood diameter	33	200	6600	1248470	C

Source: [2]

Graphical presentation of Pareto analysis along with Lorenz graph for the cumulative cost of defect correction is presented in Figure 1.

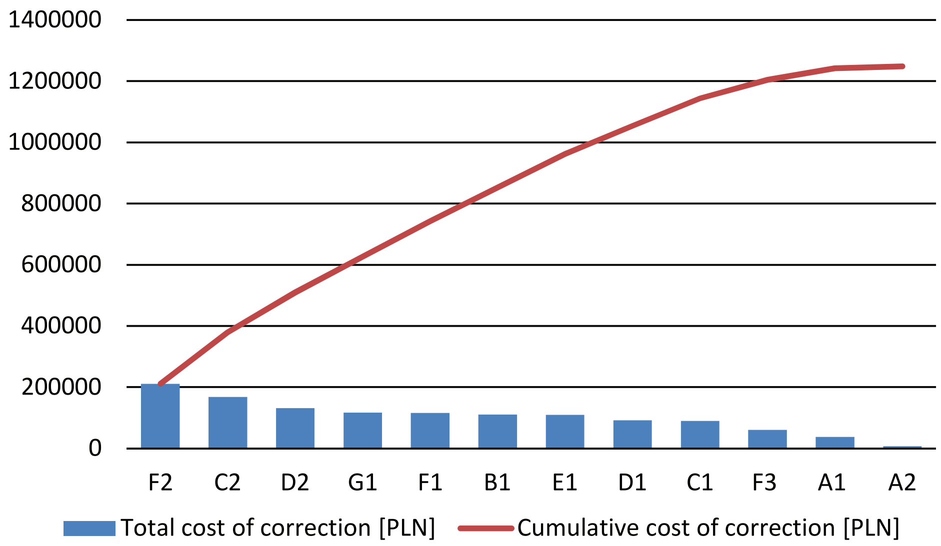

Fig. 1. Pareto-Lorenz chart for identified defects in the paper production process
Source: [2]

The analysis shows that the defects that generate the highest costs (80% of total costs), i.e. the defects included in Group A in Company X, are:

- F2 - too thick ribbon,
- C2 - not properly sorted chips,
- D2 - bad consistency of mass,
- G1 - inadequate paper cutting,
- F1 - insufficiently filled form,
- B1 - inaccurately cleaned wood rollers,
- E1 - insufficiently whitened mass.

The results also show that two of the identified defects of A Group are related to the same stage of the production process - paper machining. These are defects F1 (insufficiently filled form) and F2 (too thick ribbon).

After identifying the defects generating the highest costs in the production process, it was decided to identify the main causes of their occurrence. For this purpose, a cause-effect diagram, also known as the Ishikawa Diagram, was used.

2.2 Application of Ishikawa Diagram

The Ishikawa Diagram allows to present in a structured way, in graphical form, a set of factors affecting the outcome of the process, a set of causes generating a problem [1]. Using the cause-effect diagram, the knowledge of experts, operators, employees is used to produce a diagram, which organizes the knowledge of a specific, strictly defined problem and gives it a clear structure. The cause-effect diagram is known as the Ishikawa diagram or the fishbone diagram. The fish head is the goal (effect) we have achieved, and the reasons that interfere or help it are grouped into groups of interrelated issues, presented on the main axes [3]. Usually, problems are sorted according to the "5M" concept (Method, Material, Man, Machine, Management). So, the Ishikawa diagram allows to identify the causes of the problem, allows to prioritize them (assess their impact on the appearance of nonconformities), and facilitate the determination of appropriate corrective measures for the problem being analyzed.

In the example shown, the analysis using the Ishikawa Diagram was subject to all the defects from A Group. For the purposes of this article, diagrams for F2 and C2 defects are presented. Enterprise X was involved in a brainstorming session in which employees directly involved in the production process were involved to identify possible causes of defects in the paper production process. The identified causes were grouped into categories according to the 5M concept. Complete cause-effect diagrams for the two selected defects from A Group are shown in Figures 2 and 3.

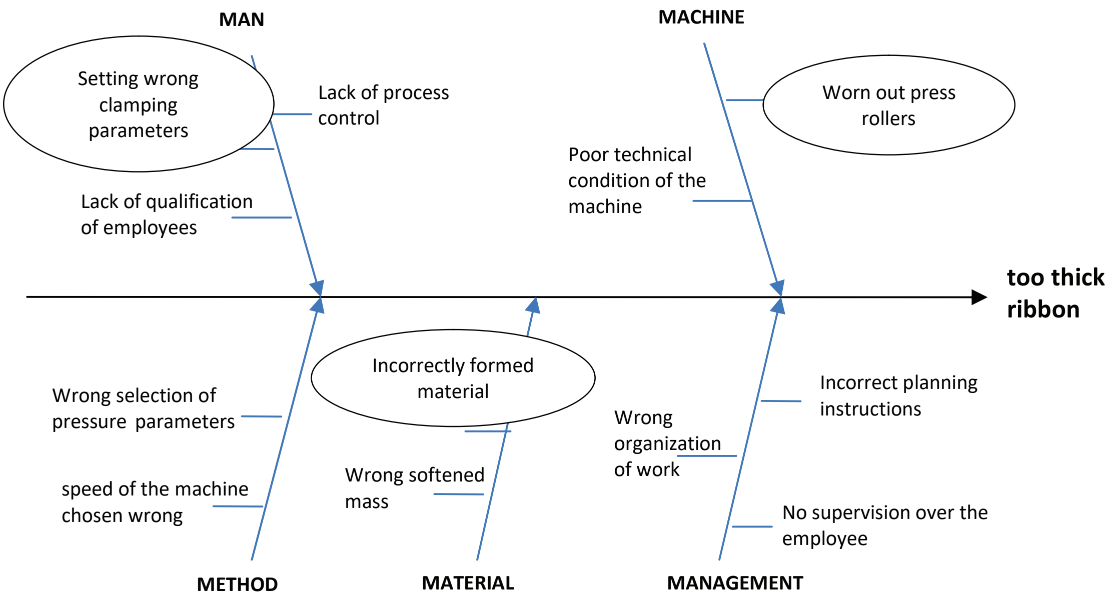

Fig. 2. Ishikawa Diagram for F2 defect - too thick ribbon
Source: [2]

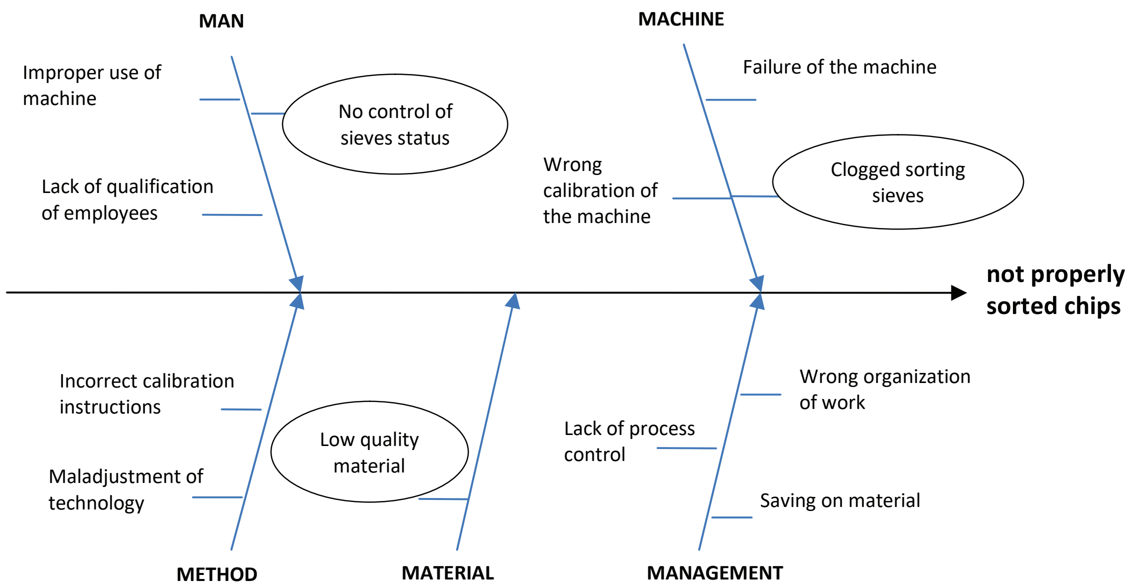

Fig. 3. Ishikawa Diagram for C2 defect - not properly sorted chips
Source: [2]

The analysis of the diagram allowed for the identification of critical causes, i.e. those having the greatest impact on the development of defects. For critical causes, corrective measures have been proposed to prevent re-occurrence of defects in the paper production process which generate the highest costs. The use of the Ishikawa diagram for the F2 defect (too thick ribbon) has allowed to determine the following critical causes: category people - setting wrong clamping parameters, machine category – worn out press rollers and material category - incorrectly formed material. Critical causes for C2 defect (not properly sorted chips) have been identified: in the category of people - no control of sieves, in the machine category - clogged sorting sieves, and in the material category - low quality material. After some time the corrective measures have been applied for the identified critical causes for A Group defects the Pareto analysis and the Ishikawa diagram should be repeated to identify new problems that have not been previously identified.

Conclusion

For companies that aim to produce high quality products, an indispensable part of running a business should be continuous improvement of the processes and products that result from them. In the process of improvement, a variety of methods and tools are used to address the different stages of the product life cycle. Quality engineering comes with a set of tools that help to improve the technical aspects of the quality of processes and products. This article presents an example of using two selected tools to improve the paper production process. In the first place, using the Pareto analysis, the defects were classified in terms of their relevance to the company considering the costs they generated. In the second step, the cause of these defects was identified using the Ishikawa diagram and the critical causes of the defects in the paper production process were identified. Correctly applied corrective actions will improve the situation and reuse of the proposed tools will allow continuous improvement of the production process.

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NARZĘDZIA INŻYNIERII JAKOŚCI W DOSKONALENIU PROCESU PRODUKCYJNEGO

Streszczenie: W niniejszym artykule wskazano na istotną rolę narzędzi inżynierii jakości w doskonaleniu procesów. Jako przykład do analizy wybrano proces produkcji papieru. W celu usprawnienia zaistniałej sytuacji zaproponowano zastosować dwa narzędzia. W pierwszej kolejności wykorzystano metodę ABC aby zidentyfikować te wady, które generują najwyższe koszty w procesie wytwórczym. Następnie dla tych wad zastosowano diagram Ishikawy, który pozwolił na określenie przyczyn krytycznych wad występujących w analizowanym procesie wytwórczym.

Słowa kluczowe: jakość, narzędzia, inżynieria, analiza Pareto, diagram Ishikawy, ciągłe doskonalenie.