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QUALITY CONTROL IN PRODUCTION PROCESSES

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The tools for quality management are used for quality improvement throughout the whole Europe and developed countries. Simple statistics are considered one of the most basic methods. The goal was to apply the simple statistical methods to practice and to solve problems by using them. Selected methods are used for processing the list of internal discrepancies within the organization, and for identification of the root cause of the problem and its appropriate solution. Seven basic quality tools are simple graphical tools, but very effective in solving problems related to quality. They are called essential because they are suitable for people with at least basic knowledge in statistics; therefore, they can be used to solve the vast majority of problems.

Keywords: Ishikawa diagram; Pareto diagram; statistical process control; metrology; welding

The process of continuous quality improvement in organizations requires the active use of management tools by organization managers in order to improve the quality of production. Nowadays, there are many quality management tools, so selecting the appropriate tools is not always easy (Krakowiak-Bal and Salamon, 2011). Statistics has a unique place in the modern society (Máchal et al., 2013). It is used in the analysis of social and economic phenomena, not only in science and research, but also as an important instrument of state policy (Kadnár et al., 2014). The term statistics comes from the Latin word 'status', which means a condition or a state (Korenko and Kaplík, 2011).

Statistical methods were introduced in Japan as the third stage in quality management (after World War II), and later in Europe. Statistical methods are an important part of the analysing methods of measured data. They are an essential tool in quality management (Korenko et al., 2015). The most basic techniques are simple statistical methods. They consist of seven basic statistical methods: Ishikawa diagram, Pareto analysis, histogram, flowchart, checklist, correlation diagram, and control charts. These methods are one of the many tools for improving the process of performance according to the DMAIC (Six Sigma improvement cycle) (Kučera et al., 2014). The appropriate application of simple statistical methods is essential for management and for quality assurance and implementation of the quality management system (Kadnár et al., 2011).

In corporate practice, basic statistic functions help the analysts to comprehend the data purpose and content, to obtain information from them in the form of, e.g. daily records for a given month, but also in an aggregate form, e.g. as average data for that month (Korenko et al., 2013).

The goal was to apply the selected simple statistical methods: flowchart for document control, checklist for determining the checks in the manufacturing process, histogram, Pareto diagram, and Ishikawa diagram for the evaluation of internal discrepancies in the production process, and to solve problems by the given methods (Korenko et al., 2012). Implementation was performed in the manufacturing organization dealing with machine production, at the division of production of sheet metal assemblies.

Material and methods

Simple statistical methods were applied to a selected engineering organization. During processing, the following steps were implemented:

- definition of simple statistical methods (both widely used and newly designed methods);
- creating the right team of employees in the organization;
- retraining the staff at all levels (from production to management);
- creating a flowchart concept suitable for the use in the organization;
- incorporation of flowchart;
- designing the checklists for each operation;
- processing of checklists, monitoring the production implementation in checklists;
- feedback from production to the implementation of flowchart and checklist;
- processing of internal discrepancies data into a summary table;
- histogram processing;
- evaluation of discrepancy using the Pareto diagram;
- identification of the problem source using the Ishikawa diagram;
- identification of appropriate measures for problem elimination.

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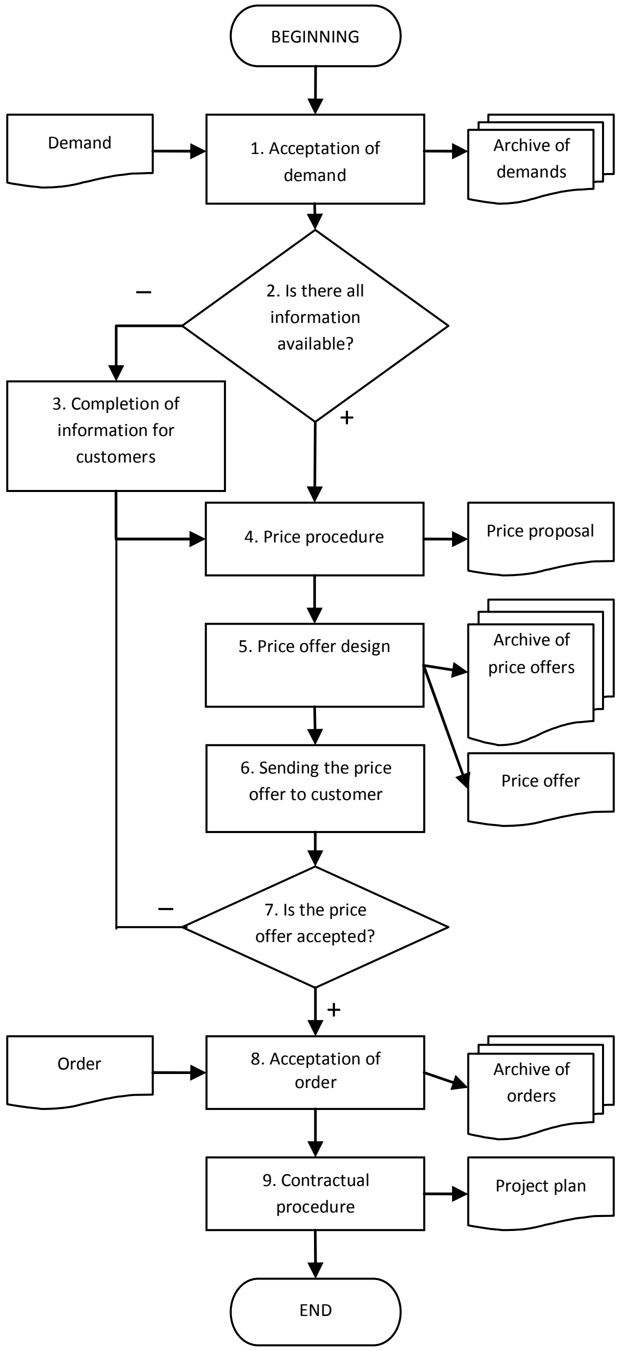
Results

The selected organization in the engineering industry offers development and design in CAD/CAM systems. With the help of CNC technologies (CNC – Computer Numerical Control), the production is accurate and fast. It disposes of the Certificate ISO 9001 (2008), which guarantees the stability of processes.

The production division of sheet metal assemblies is involved in the production of sheet metal parts in small batches by means of universal CNC machines. These

PROCEDURE (What?)



DESCRIPTION (How?)	RESPONSIBILITY (Who?)	Record
1. The organization can get demand from the customer (by acquisition or spontaneously) by mail, telephone or personal contact. After receipt of demand, it is necessary to determine the timeliness and credibility of demand and subsequently to register the demand.	Business manager (BM) (BM assistant) BM	Demand
2. When processing the demand, it is necessary to verify the completeness of the information (specified, unspecified by customer, determined by organization, as well as legislative requirements) in order to create the most accurate price offer.	BM	
3. If some information is missing, incomplete or conflicting with each other, it is necessary to contact the customer and add the information.	BM, head of design dep., production dep., manager	Demand
4. The role of the price procedure is demand review (revision of product requirements) in terms of design, manufacture, date and price in order to determine the requirements for demand.	BM	Price offer, record from price procedure
5. After definition of requirements for demand, price and date are quantified, thus the main components of price offer are formed.	Manager (BM assistant) BM	Price offer
6. Created and approved price offer is sent to the customer.	BM (BM assistant)	Mail
7. If the customer agrees with the price offer, he promptly sends the order. In case the price offer is not approved, the revision of demand and creation of new price offer is necessary. If there is no place for negotiation of price offer with the customer, the process is rejected and terminated.	BM, head of design dep., production dep.	
8. After a positive response to the sent price offer, the organization receives the order, which is registered.		Order
9. Verification (revision of product requirements) and order planning is the role of the contractual procedure. There is established a project plan (schedule), which splits the time of order into individual processes and activities.		Project plan, record from contractual procedure

Figure 1 Example of the process flowchart relating to the customer

parts are subsequently welded, installed or riveted into the assemblies and apparatuses that can be shipped with a coating (painting, powder coating, zinc coating, etc.) to customers either as final products, or for further mounting of assemblies. Production by means of universal machines for laser cutting, punching, bending and folding begins after the initial processing. There are eccentric presses for bending and forming and machines for CNC turning and milling. At the division, there is also one robotic welding work station in addition to manual welding (TIG – Tungsten Inert Gas, MIG – Metal Inert Gas) and scoring stations.

Ensuring the quality and its continuous improvement is an essential task and duty of every employee in the company, however, it is the that is primarily responsible for the quality of the performed work, and this responsibility can not be held by employees in any case.

The aim of this paper was to implement and maintain simple statistical methods to control procedures. Firstly, we implemented only few simple statistical methods. Selection of the appropriate methods was narrowed to following according to their suitability: flowchart, checklist, Pareto diagram, Ishikawa diagram, and histogram.

Table 1 Non-conforming products for the given month (source: authors)

Number	Date	Number of unit	Quantity of units	Found discrepancy	Type of discrepancy	Cause of discrepancy	Solution (optimal)
1	2.12.2013	RP46596G	1	poor bend	6	inattention of operator	operator should be instructed to comply with dimensions
2	2.12.2013	Kone 0343202	50	exceeding weld in matrix	8	inattention of operator	operator should be instructed about technological procedure
3	2.12.2013	LST ZN 607	50	overflown weld in corners	8	failure to comply with technological procedure	operator should be instructed about technological procedure during welding
4	2.12.2013	ASA-W022	22	poorly grinded weld from balls	8	insufficient lighting	operator should be instructed about technological procedure
5	2.12.2013	AIR 800047	19	non-grinded weld after spot welding	8	missing operation	the supplementary operation should be added.
6	2.12.2013	Kone 0343202	25	exceeding weld in matrix	8	inattention of worker	operator should be instructed about technological procedure
7	3.12.2013	ASA-W 16040	1	poor grinding to dimension 102	8	inattention of worker	operator should be instructed about technological procedure
8	3.12.2013	ASA-W 16040	1	poor grinding to dimension 102	8	inattention of worker	operator should be instructed about technological procedure
9	3.12.2013	LST ZN 607	50	welded raw welding contacts	8	failure to comply with technological procedure	technological procedure should be re-adjusted
10	4.12.2013	ASA-W 0281	6	unequal parts no. 2 after welding	8	failure to comply with technological procedure	operator should be instructed about technological procedure
11	4.12.2013	Kone 06432	15	dimension 250 is approx. 252	6	failure to comply with technological procedure	templates for checking of the bends should be pre-produced.
12	4.12.2013	Kone 06432	20	dimension 250 is approx. 252	6	failure to comply with technological procedure	templates for checking of the bends should be pre-produced.
13	5.12.2013	ASA-W 1666	1	poorly welded grid	8	–	operator should be instructed about technological procedure

			Error card							Card number:			
		Name of product				Number of drawing			Operation number: 60			Inspection: operator, scheme operator	
		Joist				D004609							
Week		Prescription of the quantity of measured units, min.:						every unit		Act: welding			
Order (waybill number)												Sum	
Date												Evaluation	
Number	Measured parameters	Number of non-conformities										units	%
1	Surface defects of weld												
2	Size a3												
3													
4													
5													
6													
7													
8													
9													
Batch of filler material for welding												X	X
Sum of non-conformities													
Quantity of units													
Quantity of checked units													
Quantity of „OK“ units													
Quantity of disagreed units													
Name of operator													
Name of scheme operator													
Number of non-conforming units during scheme													
Result of random technical inspection												Worst parameter number:	

Figure 2 Error card for welding
Note: Record only the number of unrecoverable disagreements and immediately notify the supervisor.

Flowchart

The flowchart is used to describe simple graphical processes by use of symbols that are linked by arrows. We wanted to start using the diagram in the organization in order to describe processes in controlled documentation. In addition to quality objectives, the controlled documentation is written for each division separately. We are aware that text is sometimes very difficult to comprehend, and it would be easier to understand if the flowchart would be added to each controlled document just before the description of the process. The process is presented in more comprehensive manner by flowchart, rather by several pages of text. The first step was to make a review of controlled documentation, to check for any differences from the current process and subsequent correction.

Checklist

The next step was to incorporate the checklists for production and quality needs. Checklists were called error cards. They were made for all manufacturing operations. They were specific because they were developed separately for production of each single product. Operators had to perform and record the check and they knew exactly what had to be checked. By checking the parameters of quality, they participate in quality procedures, and thus take responsibility for quality. The created error card for welding is shown in Figure 2.

Figure 2 shows the error card for welding of a certain type of product. The operator knows what parameters to check and in what time intervals they should be checked. He must regularly record the checks, and thus the check is performed. Such cards are made for the each type of product and there is one unique card for each single operation in production process

Ishikawa diagram, Pareto diagram and histogram

The first step was to create a certain kind of inter-operational inspection, with data written into a table so that data could be evaluated by means of statistics. When implementing the inter-operational inspection, we came to conclusion that the recording of errors is not sufficient. However, it is also necessary to ascertain the sources of discrepancies and to find an appropriate solution.

At first, it was necessary to create a list of internal discrepancies. Table 1 contains all discrepancies occurring during the production. It contains the following basic information: serial number, date (when the discrepancy was observed), quantity of units (quantity of parts with discrepancy), observed discrepancy (brief description of discrepancy), type of error (error code list), source of error (why the error occurred), and solution to the occurred error (immediate measure determined by quality).

For further data processes, we had to create the error code list. We put down the list of errors that may occur, and we assigned number to each separate error When the data was processed and recorded for the month, it could be evaluated. First, we used the histogram that graphically pictured the types of errors which occurred most frequently. Figure 3 indicates that the error no. 1 is the most frequent error (29 times), which represents

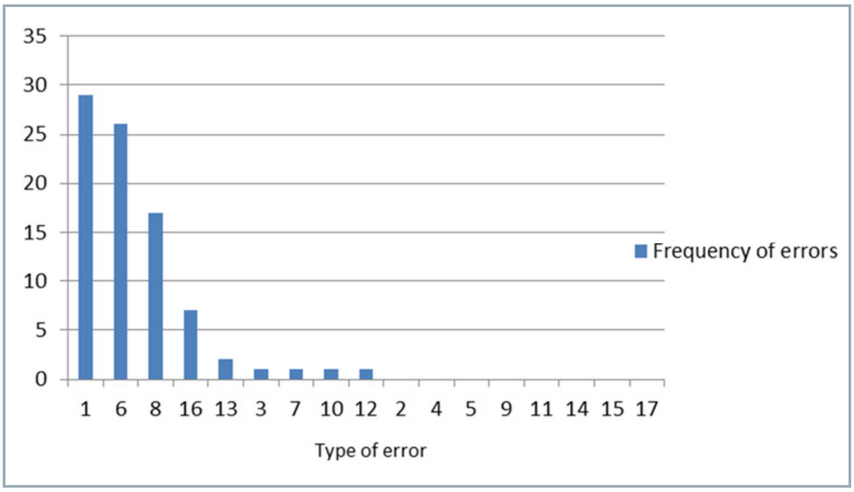


Figure 3 Histogram of frequency of errors per month

Table 2 Table for Pareto diagram

Type of error	Frequency of errors	Cumulative frequency	Cumulative frequency (%)
1	29	29	34
6	26	55	65
8	17	72	85
16	7	79	93
13	2	81	95
3	1	82	96
7	1	83	98
10	1	84	99
12	1	85	100
2	0	85	100
4	0	85	100
5	0	85	100
9	0	85	100
11	0	85	100
14	0	85	100
15	0	85	100
17	0	85	100

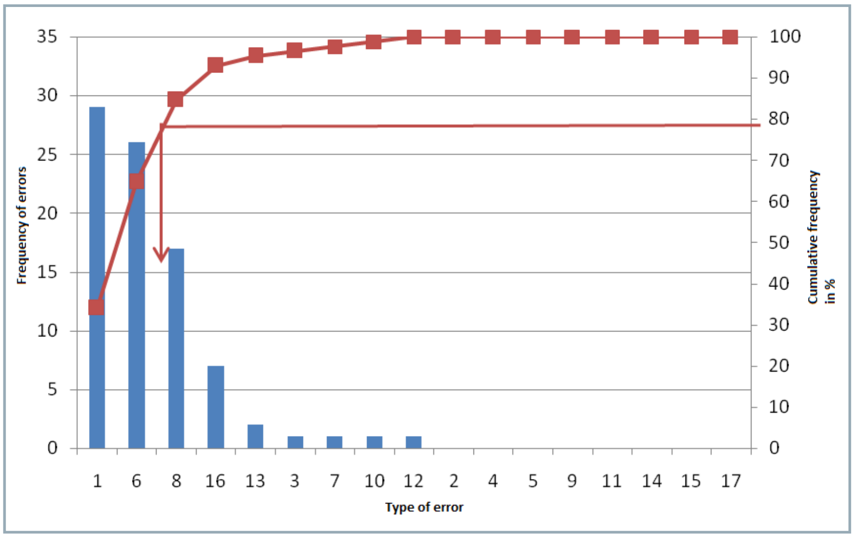


Figure 4 Pareto diagram

the 'Technological procedure: Swap operation' according to the code list.

The histogram is sufficient for observation of the data, but for further processing, it is necessary to produce the Pareto diagram. The first step was to create Table 2, from which it would be possible to create the Pareto diagram. At first, we had to sort the data from the highest to the lowest and then we added the column called 'Cumulative frequency' and calculated the data in percentage in column 'Cumulative frequency (%)'.

From the table, we could subsequently create the Pareto diagram shown in Figure 4. The diagram indicates that the error no. 1 (Technological procedure: Swap operation) and no. 6 (Bending: unobserved rate, poor program) were of the greatest frequency. The diagram also indicates that if we eliminate these two errors, we eliminate almost 80 % of the errors. That means, 20 % of discrepancies remove 80 % of the causes. According to examination, we later observed that the error no. 1 was the only one extreme error in the given month, and it was occurring due to insufficiently clear drawing documentation from the customer. Therefore, we decided to explore the second most frequent error no. 6.

In order to inspect the errors more deeply, we decided to use the Ishikawa diagram, also called as the fish bone. It was necessary to nominate a team of people who would solve the issue. We decided to choose an operator from each department: quality, production (master and operator who is familiar with the machine), and technical department. The team of operators generated the Ishikawa diagram shown in Figure 5. After completion of the diagram, each operator received six points. Three points were to be distributed to the most important cause of the error in the first round, two points in the second round, and one point in the third round. The incorrect angle of the machine equipment and material thickness were determined as the most important causes of errors.

This resulted in the need for buying a metering device, which would meter the bend angle and material thickness during bending. The device communicates directly with the machine and it automatically distribute the higher amount of force to the bended parts during bending.

This measure can eliminate almost 80 % of the problems.

Conclusion

Despite their simplicity, the simple statistical methods are very effective tools in solving quality problems. They are suitable for people with at least

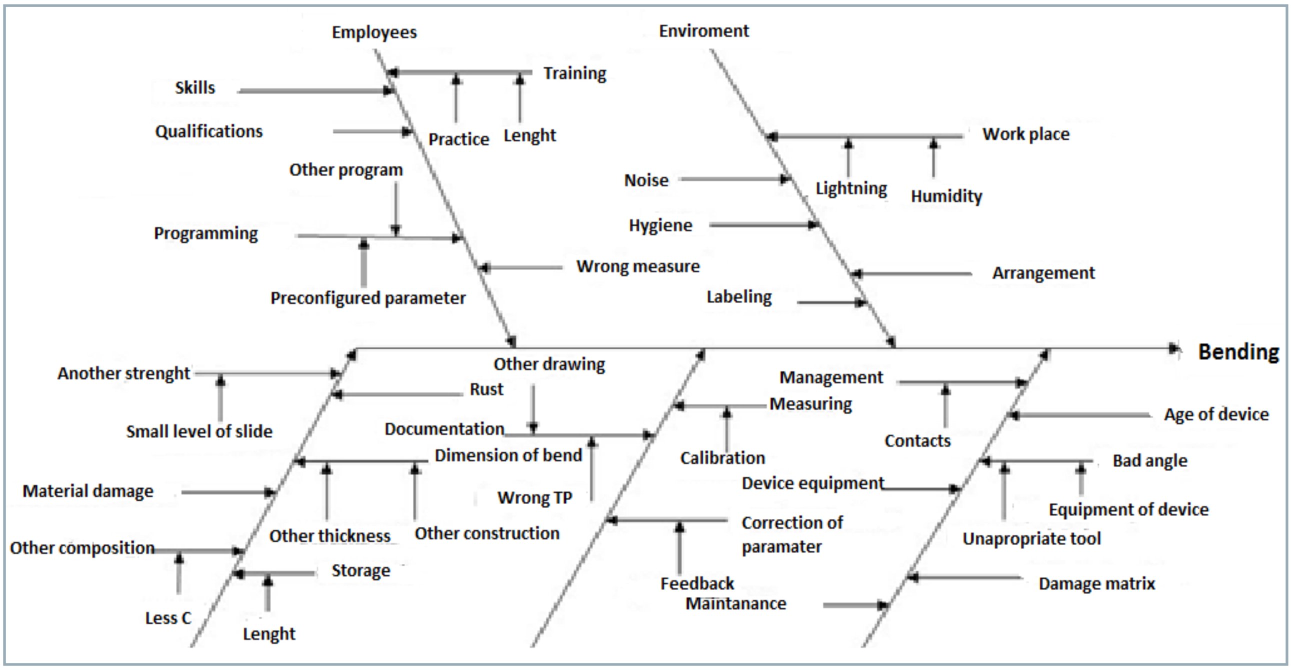


Figure 5 Ishikawa diagram

basic knowledge of statistics. It is possible to use them at all levels and departments of the organization. Simple statistical methods represent the part of the analytical tools for analysing problems. They help to identify and develop optimal solutions which are later on standardized. The following simple statistical methods were applied to the operation in the selected company:

1. The flowchart was used to describe the process in controlled documentation. The implementation of the flowchart to controlled documentation resulted in the fact that everyone could benefit from it. The flowchart described the process in a visual way and thus it was easier to comprehend.
2. The checklist was used to control inspections during the process. The obligation to fill the checklist actually forced the operators to perform the checks of the products. This measure led to reduction of internal defects in the process by approx. 60 % and external defects by 30 %. However, this method can provide proper results only after long-term assessment (approx. one year of observation).
3. The histogram and Pareto diagram were used for better presentation of the results of internal non-conformities in the process and for better identification of the main causes of non-conformities. The Ishikawa diagram subsequently identified proper solutions for elimination of the sources of non-conformities. The histogram, Pareto diagram and Ishikawa diagram were thus used for problem (non-conformity) solving, and for identification of the main causes and adequate solutions to the problems. However, the assessment of results can be performed only after a longer time period, the solution of the most frequent non-conformity problem (buying the metering device for bending) appears to be effective.

The comprehension of simple statistical methods represented the necessary and essential step for application of the methods in the organization. The implementation of simple statistical methods provided a more efficient work, and thus will be used in the future in order to maintain the established standards. The next step will be the introduction of other tools for quality management to the company.

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