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STATISTICAL PROCESS CONTROL IN THE MAINTENANCE

22.1 INTRODUCTION

22.1.1 Statistical process control

No process, be it a production or service one, is without errors. Neither products nor services are entirely replicable. This is due interferences which determine the variability of parameters and process indicators. The subject literature distinguishes two types of interferences: random and special [1]. Random interferences are, according to PN-ISO 3534-2:2010: *"Factors, usually multiple, of which every individual one has small significance, causing variability…"* [10]. We should, therefore, see them as inseparable elements of every process, which cannot be foreseen and which affect the "natural" process variability. The same standard [10] describes special interference as: *"A factor (usually systemic) which can be detected and identified as one that causes changes in the quality properties or level of the process".* Improvement of processes should therefore focus on identifying the causes creating special interferences and try to eliminated them or, at least, reduce their influence. The most popular method used for identifying special interferences is statistical process control (SPC) based on the so-called Shewhart's control charts [12].

From the time of their first use in 1924, control charts evolved and many modifications are known today [13]. Depending on the type of data that can be obtained from the process, control charts can be divided into two basic groups: control charts for measurable properties (e.g. length, weight, etc.) and control charts for unmeasurable characteristics (countable, e.g. number of defects) [11]. In the first group, we can distinguish the following types of charts: mean and range chart, mean and standard deviation chart, median and range chart, individual observation chart, moving range charts, and others. Control charts for countable characteristics are, predominantly: non-conforming units in a sample chart (np chart), fraction of non-conforming units in a sample chart (p chart), number of nonconformities per unit chart (u chart), and others.

The choice of the right chart depends on many factors, the most important of which is the number and frequency of samples taken for testing. Regardless of which chart is chosen, in order to perform analyses and interpret the results it is crucial that the data used in them have a distribution close to normal. If the distribution does not exhibit the properties of a normal one, other types of charts should be used, e.g. Burr charts [7].

22.1.2 Maintenance

Maintenance processes are typical supporting, service-oriented processes [3]. The basic aims of these processes are: conserving, improving, repairing and preparing technical resources [8]. Realising all of the aims requires sufficient resources and time. One of the paths leading to improvement of exploitation processes is reducing the time of stoppages caused by breakdowns. Generally, the time required to fix a breakdown can be divided into the following elements:

– passive time (administrative delay, waiting for staff, spare parts and consumables as well as necessary breaks),
– active time (diagnostics, repair, restarting the machine and checking its operation) [6].

Thanks to using statistical process control it is possible to monitor the stoppage time and identify those breakdowns for which the stoppage times are too long, as well as observe other anomalies in stoppage times. Following that, it is necessary to discover the causes of anomalies and develop improvement and preventive measures.

22.2 EXAMPLE ANALYSES OF SELECTED STOPPAGES

22.2.1 Methodological assumptions

In the case discussed the element chosen to improve the maintenance process is the machine stoppage time due to breakdown. Implementation of the SPC method for improving maintenance processes was conducted on the basis of data pertaining to breakdowns in a Silesian production company. The data come from a maintenance supporting system and contain information from a period of three years. The breakdowns analysed are connected with machines key to the company, i.e. plastic extruders. Breakdown cases of a manual extruder's blower used in the process of joining pipes made of polyethylene were chosen for further analysis. Fifty-two such breakdowns occurred in the period discussed. Individual stoppage times (in chronological order) are presented in Table 22.1.

Since a breakdown is a singular occurrence, a Xi-MR type chart was used, i.e. an individual observation and moving range chart used for single sample studies in cases where, e.g. testing the product is very expensive or multiple samples cannot be gathered in a small-series production.

In the case of control charts for numerical evaluation, which include Xi-MR charts, the requirement is that the results have a distribution as close to normal as possible.

Table 22.1 Stoppage times

Breakdown No.	Stoppage time [h]	Breakdown No.	Stoppage time [h]	Breakdown No.	Stoppage time [h]	Breakdown No.	Stoppage time [h]
1	60	14	65	27	50	40	44
2	15	15	50	28	60	41	90
3	35	16	75	29	70	42	110
4	20	17	100	30	75	43	45
5	65	18	25	31	50	44	25
6	60	19	30	32	55	45	50
7	75	20	40	33	60	46	55
8	60	21	90	34	70	47	60
9	50	22	25	35	65	48	75
10	115	23	55	36	35	49	55
11	40	24	50	37	45	50	35
12	70	25	65	38	25	51	50
13	75	26	45	39	75	52	35

To test the hypothesis on the normal distribution of the values, the Shapiro-Wilk test was chosen, which is used for small-sized samples. For the purpose of the test, an H0 hypothesis stating that the data distribution is normal was assumed. STATISTICA 12.5 software was used to test the hypothesis and the results are presented in Figure 22.1.

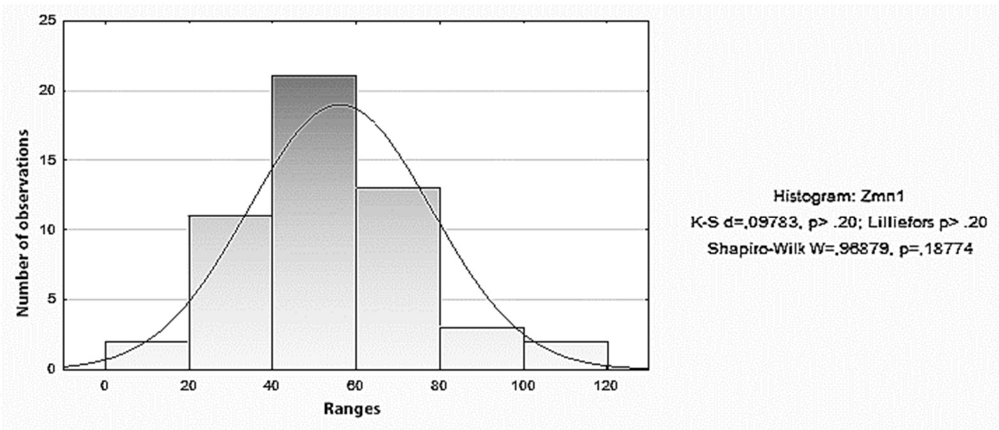

Fig. 22.1 The Shapiro-Wilk test

As can be seen in Figure 22.1 the H0 hypothesis about the normal character of result distribution was confirmed.

Data gathered in the company allowed for the calculation of the following values necessary for the creation of a control chart:

– mean result value:

$$\bar{X} = \frac{x_i}{n} = 56.13\ h \qquad (22.1)$$

– moving range value:

$$MR_i = |x_i - x_{i-1}| \qquad (22.2)$$

– mean range value:

$$\overline{MR} = \frac{MR_i}{n} = 23.27\ h \qquad (22.3)$$

– upper control limit of chart X:

$$UCL_X = \bar{X} + (2.66 \times \overline{MR}) = 118.04\ h \quad (22.4)$$

– upper control limit of MR charts:

$$UCL_{MR} = 3.27 \times \overline{MR} = 76.11\ h \quad (22.5)$$

where:

i – breakdown number,

x – stoppage time,

n – number of breakdowns,

2.66 and 3.27 – array values depending on the number of measurements.

The values calculated allowed for the creation of an Xi-MR chart comprised of a chart of individual stoppage times and a chart of the times' moving range. The results obtained are shown in Figure 22.2.

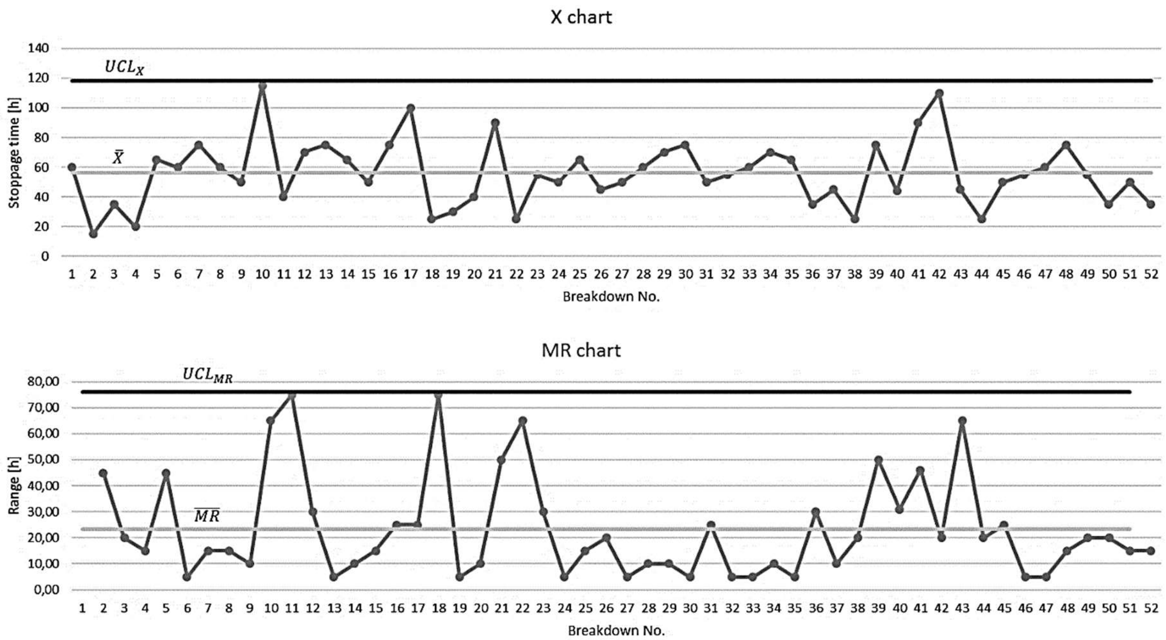

Fig. 22.2 The Xi-MR chart

The aim of improving the maintenance process is first and foremost to minimise the stoppage times caused by breakdowns, i.e. the mean value of X. Because of that it was decided to forgo marking the lower control line LCL for the X chart, which would not be useful in this case.

22.2.2 Result analysis

In order to determine the process capability, the process capability index Cp was used, which is calculated using the formula:

$$Cp = \frac{|UCL_X - LCL_X|}{6\sigma} \quad (22.6)$$

In the case discussed, the Cp index is 0.94 and indicates that the process has too large a spread of individual results (the width of the area limited by the UCL and LCL lines) and LCL is smaller than the value of 6σ – the aim value should be approx. 1.33.

When setting out to improve the process analysed, we should first and foremost:

1. Identify the causes for very long stoppage times (points exceeding or lying on the UCL_X line – breakdowns No. 10, 17 and 42.
2. Identify the causes of very big variations in the stoppage times (points exceeding or lying on the UCL_{MR} line – breakdowns 10 and 11 as well as 17 and 18).

Subsequently, when all of the causes of the aforementioned cases have been eliminated, attention should be paid to other anomalies in the diagrams on Xi-MR charts, such as:

1. Trends, i.e. sequences of points (rising or falling) in the X chart, e.g. points from 26 to 30 (Fig. 22.2).
2. Several points lying above or below the central line (mean X).

The abovementioned anomalies can also indicate the presence of special interferences in the process.

22.2.3 Process improvement

A properly maintained control chart shows anomalies in the analysed process which should be eliminated in the following stages of improvement. An example procedure algorithm was presented in Figure 22.3.

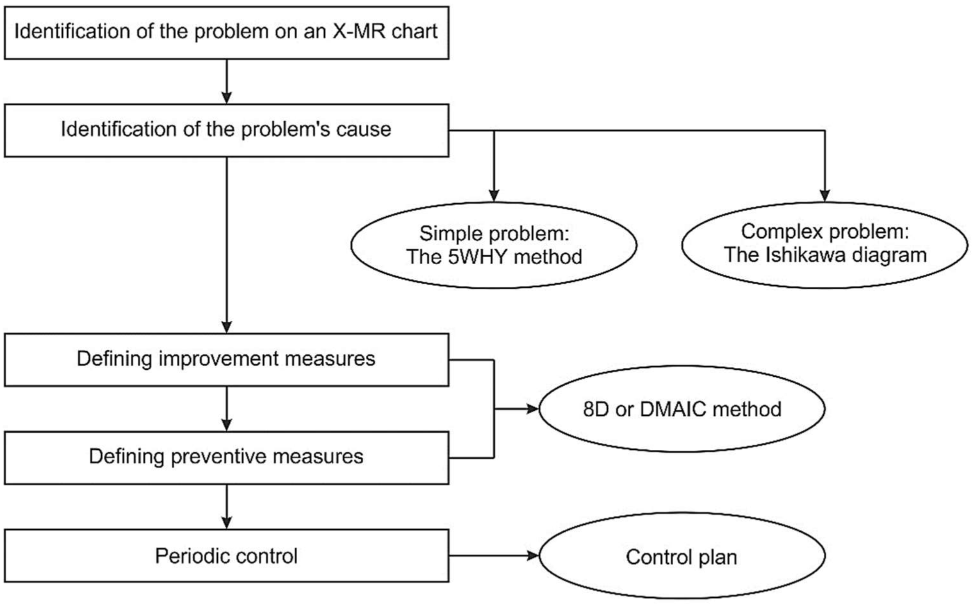

Fig. 22.3 Improvement algorithm

Quality management tools should be used for the identification of non-compliance causes. The 5WHY tool [2, 5] can be used in the case of simple problems. If finding out the causes of the anomaly is a more complex process, the Ishikawa diagram (5M or 6M) or relationship diagram [9] can be used.

Methods such as 8D or DMAIC can be used to develop and implement improvement measures, as their methodology also guarantees preserving the preventive measures in the future thanks to systemic solutions and implementing their results in the control plan [4].

22.3 CONCLUSION

Using the methodology contained in the foundations of statistical process control for the improvement of the maintenance process can:

– provide constant and systematic monitoring of the failure removal process,
– guarantee the capability for quick reaction in case of special interferences occurring in the process.

By using the results obtained from control charts along with quality management tools and methods used for identifying causes of problems, the maintenance manager is given a powerful, effective and efficient instrument which allows for quickly developing and implementing measures aimed at improving process efficiency.

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STATISTICAL PROCESS CONTROL IN THE MAINTENANCE

Abstract: *Improvement of processes connected with maintenance is important from the perspective of the company's productivity. The proper functioning of the departments responsible for maintaining technical assets in working order affects the production efficiency, safety of the operating personnel, quality of the products and the effectiveness of realisation of the production plans. One of the most important tasks of the maintenance department is minimising the length of stoppages caused by breakdowns. The article presents a proposal of using SPC tools for the constant improvement of the maintenance process. Implementation of static process control allowed for identifying the major problems which lengthen the breakdown removal time, as well as continuously monitoring the breakdown removal process. The study is based on breakdown data gathered in a production company over the period of three years.*

Key words: *maintenance, improvement, process, SPC, failure, downtime*

STATYSTYCZNA KONTROLA PROCESU UTRZYMANIA RUCHU

Streszczenie: *Doskonalenie procesów związanych z utrzymaniem ruchu jest istotne z punktu widzenia produktywności przedsiębiorstwa. Od sprawnie działających służb odpowiedzialnych za utrzymanie w sprawności środków technicznych zależy wydajność produkcji, bezpieczeństwo obsługujących, jakość wyrobów oraz skuteczność realizacji planów produkcyjnych. Jednym z najważniejszych zadań utrzymania ruchu jest minimalizowanie długości trwania przestojów spowodowanymi awariami. W artykule zaprezentowano propozycję zastosowania narzędzi SPC do ciągłego doskonalenia procesu utrzymania ruchu. Implementacja statystycznej kontroli procesu umożliwiła identyfikację najważniejszych problemów wpływających na przedłużanie czasu usuwania awarii oraz stały monitoring procesu usuwania awarii. Opracowanie opiera się na danych o awariach zbieranych w jednym z przedsiębiorstw produkcyjnych w okresie trzech lat.*

Słowa kluczowe: *utrzymanie ruchu, doskonalenie, proces, SPC, awaria, przestój*