Data Analysis and Production Process Control

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Abstract. Production process control is an important issue. Production processes are affected by many factors and some processes are very complex. Statistical process control (SPC) can apply statistical methods to monitor and control production processes for quality improvement. SPC methods include control charts and process capability analysis. This paper presents a method for continuous production process improvement. The control flow of the proposed method is developed. The method identifies the production process to be improved, collects and verifies data, applies Xbar-R control chart analysis and process capability analysis, analyzes the causes, forms measures for improvement, and takes actions for the improvement. An application example is provided. The results of the study indicate the quality improvement of their production process. This research can provide a reference for companies to apply SPC methods and statistical tools and take process capability analysis and control chart analysis for production process control to improve the quality of production processes.

Keywords: Production Process Control, Xbar-R Control Charts, Process Capability Analysis.

1 Introduction

To obtain competitive advantage, many companies aim to develop high quality products fast. Some production processes of manufacturing products are very complex and it is difficult to control quality. Statistical process control (SPC) can monitor processes, detect changes, and control process quality by applying appropriate control charts [1].

Process capability analysis is a method of SPC and can be used for production process quality control. Process capability analysis plays an important role in applying SPC method for quality management. Process capability analysis should be made when a production process is stable. However, even if a production process is stable, it does not mean that the process capability satisfies a requirement. Xbar-R control charts in SPC method can be used to control a production process in the analysis and monitoring stages.

Researchers have studied the integration of automatic process control (APC) and statistical process control. For example, Holmes and Mergen [2] considered if SPC was used as a process monitoring system, APC and SPC could detect deviations from the expected behavior of a process.

Park *et al.* [1] studied the integration of APC and SPC and developed an economic cost model for the integration of APC and SPC. Their proposed model was demonstrated by numerical examples. They used different controllers in the integrated systems. They also developed a long run expected cost to investigate the use of the different controllers.

Saif [3] mentioned that APC and SPC were developed separately and applied in different industries previously. They suggested the integration of APC and SPC.

Sousa, Rodrigues, and Nunes [4] studied the production process of a mental part. They analyzed the variability of the production process, applied quality tools, identified potential causes, and proposed measures to improve product quality.

This paper applies Xbar-R control chart analysis and process capability analysis and develops a method for production process control to improve quality. An application example is provided.

2 Developed Method

Process capability analysis typically includes the following basic steps: establishing control over the process, analyzing process data, and analyzing sources of variation [5]. The Xbar-R control charts in SPC method can be used to monitor the mean and the range of process data.

The method for production process control is based on data analysis and SPC application for continuous quality improvement. The method identifies the production process, applies control charts, histogram, process capability analysis, and others, and combines them for production process analysis and control to make continuous quality improvement. The developed method includes the following steps. The control flow of the method is illustrated in Fig. 1.

Step 1. Production process identification. Identify a production process to inspect if there is any abnormality in the production process to decrease defective products for quality improvement.

Step 2. Data collection. Collect data of a production process according to the status of the production process.

Step 3. Data verification. Check and verify collected data to avoid possible errors.

Step 4. Production process analysis. Analyze Xbar-R control charts to observe abnormal variation of the production process. Make process capability analysis to detect if the production process satisfies the requirement.

Step 5. Cause analysis. Check the production process to find possible causes of anomalies.

Step 6. Production process improvement. Implement actions for quality improvement of the production process.

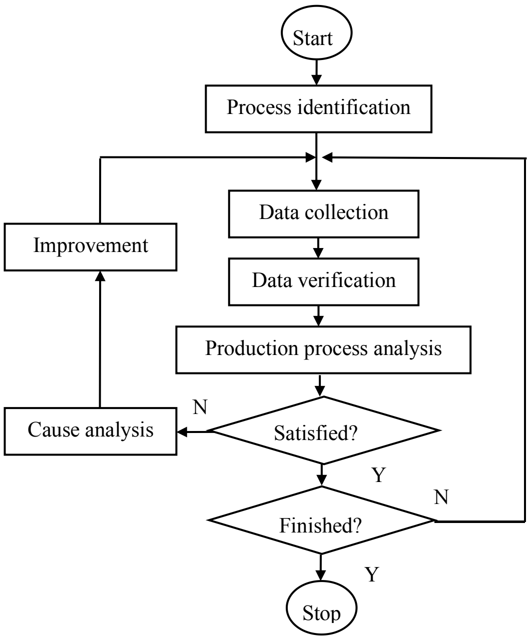

Fig. 1. Control flow of the method.

The production process needs to be monitored continuously to check if it satisfies the requirement. If the production process satisfies the requirement, no further actions are needed. If the production process does not satisfy the requirement, more actions are needed to collect data, draw control charts, make process capability analysis, find the causes of anomalies, and form measures and implement actions.

3 Application Example

3.1 Production Process Identification

The proposed method was applied to a company, Hongyang Sealing Product Company located in Guiyang City. The trial production of the engine hood sealing strips of type C automobile was taken as an example. Because the ratio of the qualified products was not high, the company decided to study the production process to identify any abnormality in the process for quality improvement.

The company formulated an quality improvement group composed of the staff from the technology department, the process department, the quality department, the workshop of the company. The quality department particularly established an expert inspection group.

3.2 Data Collection with Verification

The data collection of this product was carried out according to the production scale, staffing, and equipment. The inspection group and on-site inspection personnel specified the size of the detector and verified the normality of the measurement system. The group extracted 100 samples and took the average value each time, extracted 5 times a day from March to April in 2016. Total data sets collected are 36. Sample data of type C engine hood sealing strips are illustrated in Table 1.

Table 1. Sample data (before improvement).

Date	Data 1	Data 2	Data 3	Data 4	Data 5	Date	Data 1	Data 2	Data 3	Data 4	Data 5
3.1.	1707.4	1709.6	1711.6	1708.9	1709.4	3.19.	1711.7	1710.4	1711.0	1711.2	1711.1
3.2.	1707.4	1708.9	1709.5	1710.5	1709.1	3.20.	1711.7	1712.9	1713.0	1713.7	1712.8
3.3.	1710.6	1708.6	1711.9	1711.2	1710.6	3.21.	1713.3	1716.0	1713.1	1715.0	1714.4
3.4.	1710.6	1710.3	1710.8	1712.8	1711.1	3.22.	1710.2	1711.9	1711.9	1713.5	1711.9
3.5.	1712.9	1710.7	1712.6	1711.4	1711.9	3.23.	1711.7	1712.3	1712.3	1714.3	1712.7
3.6.	1709.8	1711.7	1712.2	1712.5	1711.6	3.24.	1712.5	1711.9	1712.7	1713.5	1712.7
3.7.	1710.6	1710.1	1712.2	1713.5	1711.6	3.25.	1712.5	1714.9	1714.3	1714.9	1714.2
3.8.	1710.6	1711.7	1711.7	1713.7	1711.9	3.26.	1711.0	1712.2	1715.2	1713.5	1713.0
3.9.	1711.4	1711.3	1710.9	1714.3	1712.0	3.27.	1711.0	1713.3	1712.5	1714.6	1712.9
3.10.	1710.2	1709.7	1710.9	1709.7	1710.1	3.28.	1711.4	1707.4	1709.4	1710.4	1709.7
3.11.	1708.6	1709.3	1709.5	1712.2	1709.9	3.29.	1709.0	1711.5	1709.2	1710.1	1710.0
3.12.	1710.2	1709.5	1708.7	1712.7	1710.3	3.30.	1708.2	1710.1	1708.7	1710.2	1709.3
3.13.	1708.6	1710.8	1709.7	1710.8	1710.0	3.31.	1710.6	1710.7	1708.2	1710.3	1710.0
3.14.	1711.0	1711.1	1710.8	1710.1	1710.8	4.1.	1707.4	1709.9	1709.6	1713.6	1710.1
3.15.	1711.0	1710.0	1710.3	1711.1	1710.6	4.2.	1709.8	1710.3	1709.9	1711.1	1710.3
3.16.	1711.7	1711.0	1710.3	1712.4	1711.4	4.3.	1710.6	1710.5	1709.8	1709.7	1710.2
3.17.	1711.7	1712.6	1711.8	1713.2	1712.3	4.4.	1708.2	1711.6	1709.9	1710.5	1710.1
3.18.	1711.0	1708.3	1711.5	1712.0	1710.7	4.5.	1709.8	1709.8	1711.9	1712.3	1711.0

The normality test was made for the data collected. The results is shown in Fig. 2. It can be seen form the figure that the sealing strips tends to be evenly distributed on both sides of the straight line. This indicates that the quality characteristics of the sealing strips tend to be randomly normal distributed.

3.3 Production Process Analysis

The data analysis of the production process was made by applying statistical software Minitab [6], Xbar-R control charts are illustrated in Fig. 3. It can be seen from the Xbar chart that several points exceed the upper limit, several points exceed the lower limit, seven consecutive points are above the centerline, seven consecutive points are below the centerline, and one point in the R chart exceeds the upper limit. The fluctuation of sampling range reflects the fluctuation within the subgroup and represents the fluctuation degree of the production process.

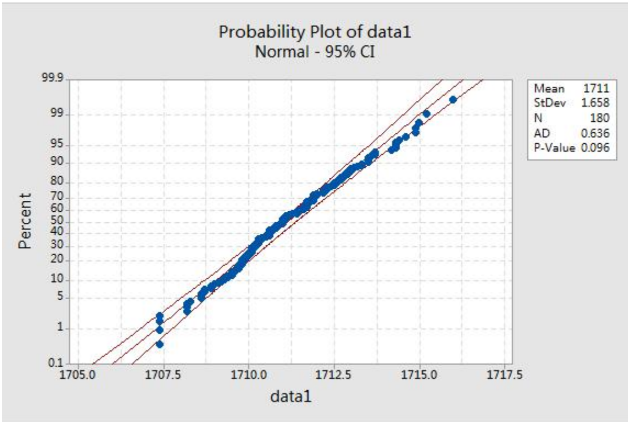

Fig. 2. Probability plot (before improvement).

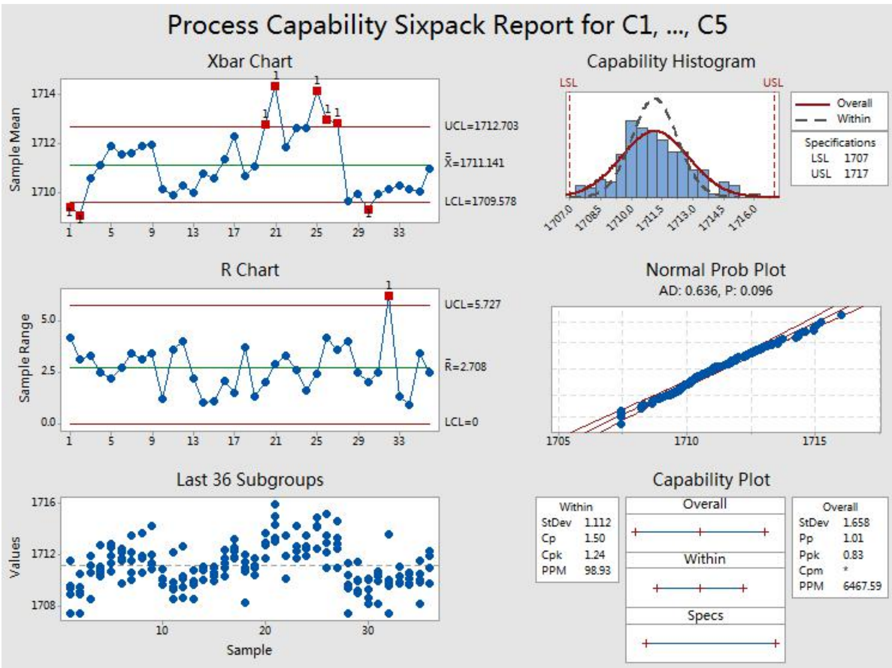

Fig. 3. Process capability analysis (before improvement).

For the collected data, the process capability index was calculated to analyze the production process capability. The following can be found from the process capability analysis of type C engine hood sealing strips. First, the center value of the normal distribution lower than the required center value in the capability histogram. Second, process capability index $C_{pk} = 1.24$ is not sufficient. It is easy to produce defective products.

3.4 Cause Analysis and Production Process Improvement

When analyzing the causes of these anomalies, the human factors and non-human factors were considered. For human factors, it was considered whether an inspector was proficient in inspection methods, whether a technical operator operated according to standards, whether a designer had design negligence, and so forth. For non-human factors, the performance of production machines, the specification of material molds, the accuracy of inspection devices, and so forth were considered. It was also considered whether production environments had changed.

The quality improvement group found the following possible causes by checking the production process and relevant records. First, on March 21st and 25th, a new production operator who had just taken up the post made improper operation. This resulted in the oversized dimension of the sealing strips produced in these two days. Second, on March 31st, the inspection device was not calibrated effectively. This might result in the error of measurement. Third, the parts shrank after extrusion. This might result in the size of the final products trend to the lower control line. Other causes included inconsistency in the rubber and mold wearing and loosening.

The quality improvement group formulated the following improvement measures based on the above analyses. These include to employ skilled operators for production, all production operators to participate in training regularly and pass the examination before they can work and operate independently, parts to be inspected after recalibration of inspection devices, the operation instruction of inspect devices to be checked, the calibration methods and requirements to be improved, and the calibration results to be recorded after each calibration. The group also required to make the parking tests of the parts after extrusion, to adjust the cutting length of the parts according to shrinkage, and to define the spot inspection standard of the mold and ensure the consistency of the mold.

The improvement actions were made, the production process was monitored, the inspection frequency of the joint rubber process was increased, and the abnormal was dealt in time. Also, the parking tests of parts was made according to different properties of rubber and different cutting lengths and parking times were determined according to shrinkage. Finally, the qualified products were obtained.

3.5 Result Analysis

The quality improvement group collected 5 * 36 sets of data for analyses, as shown in Table 2. The process capability chart is illustrated in Fig. 4. After the improvement, it can be observed from the probability diagram that the sealing strips tend to be evenly distributed on both sides of the straight line.

In the Xbar-R charts, there are no points above or below the LCL and UCL, there are no 7 points all above or below the centerline, no continuous 7 points rising or falling, and no other obvious nonrandom patterns. This indicates that there are no special factors and abnormality.

Table 2. Sample data (after improvement).

Date	Data 1	Data 2	Data 3	Data 4	Data 5	Date	Data 1	Data 2	Data 3	Data 4	Data 5
6.1.	1712.3	1710.2	1712.9	1710.6	1711.5	6.19.	1711.2	1713.3	1710.6	1712.4	1711.9
6.2.	1712.4	1711.2	1712.0	1710.7	1711.6	6.20.	1711.4	1712.4	1712.8	1712.3	1712.2
6.3.	1711.8	1711.7	1712.6	1712.7	1712.2	6.21.	1712.2	1711.9	1711.3	1712.8	1712.1
6.4.	1712.5	1710.7	1710.4	1712.0	1711.4	6.22.	1712.4	1712.7	1712.2	1711.7	1712.3
6.5.	1711.3	1711.4	1712.1	1710.4	1711.3	6.23.	1711.9	1712.8	1711.6	1713.3	1712.4
6.6.	1712.2	1712.2	1711.6	1711.8	1712.0	6.24.	1711.6	1710.1	1710.9	1712.3	1711.2
6.7.	1711.1	1710.9	1711.6	1712.1	1711.4	6.25.	1711.7	1712.5	1711.5	1712.3	1712.0
6.8.	1712.3	1710.8	1711.9	1712.2	1711.8	6.26.	1713.2	1711.3	1711.8	1712.2	1712.1
6.9.	1711.6	1710.9	1713.0	1710.9	1711.9	6.27.	1711.9	1712.3	1713.1	1711.8	1712.3
6.10.	1712.2	1713.3	1710.4	1712.2	1712.0	6.28.	1710.9	1711.7	1711.6	1711.0	1711.3
6.11.	1711.8	1712.8	1710.9	1711.3	1711.7	6.29.	1713.9	1711.7	1711.7	1713.0	1712.1
6.12.	1713.1	1711.8	1711.6	1711.1	1711.9	6.30.	1711.2	1710.9	1711.2	1712.0	1711.3
6.13.	1712.2	1711.6	1713.8	1712.6	1712.6	7.1.	1712.3	1713.5	1711.7	1712.7	1712.1
6.14.	1712.7	1711.7	1713.3	1710.9	1712.2	7.2.	1712.2	1711.3	1711.5	1711.6	1711.7
6.15.	1711.2	1710.9	1711.5	1711.3	1711.0	7.3.	1712.4	1710.8	1710.2	1712.2	1711.4
6.16.	1713.6	1712.5	1711.8	1712.2	1712.5	7.4.	1711.0	1711.1	1712.4	1712.4	1711.7
6.17.	1712.0	1713.2	1712.4	1712.5	1712.5	7.5.	1712.5	1712.2	1711.1	1711.9	1711.9
6.18.	1711.2	1710.8	1711.2	1711.5	1710.9	7.6.	1711.5	1711.1	1711.7	1713.1	1711.9

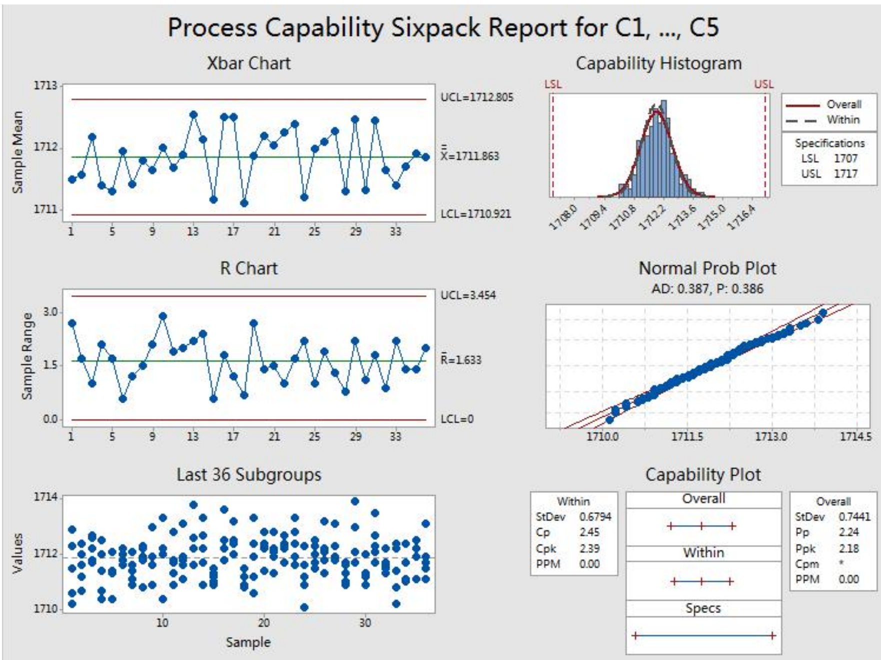

Fig. 4. Process capability analysis (after improvement).

It can be seen from the capability histogram that all the data are within the scope of the quality inspection standard. This indicates that the size is controlled near the standard value. In the capability diagram, the process capability index is $C_{pk} = 2.31 > 1.67$. This indicates that the process capability is improved. The ratio of qualified products is increased. The quality of the production process is improved. The quality department of the company monitors the production process, detect anomalies, and improve production process quality in time.

By applying Xbar-R control chart analysis and process capability analysis, the anomalies are found and the appropriate actions are taken by the quality improvement group. The result of production process improvement is achieved. With the application of SPC methods and statistical tools, the company can produce products of good quality more effectively.

4 Conclusion

In competition environments, companies face many competitors and many companies want to develop high quality products fast to obtain competitive advantage. This research can provide a reference for companies to apply SPC tools and take process capability analysis and control chart analysis to control production processes for quality improvement.

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