# Product Quality Improvement Based on Process Capability Analysis

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**Abstract.** Product quality is important to companies. Many factors affect the quality of products. Statistical process control (SPC) applies statistical methods to process control and can be utilized to improve the quality of products. This paper proposes an approach for product quality improvement based on problem analysis and statistical process control application. A framework is presented with the steps from problem identifying to problem solving to improve product quality. These steps include problem identification, problem analysis, SPC method determination, production analysis, cause analysis, and problem solving. A case study is made to a real manufacturing company. The proposed approach is applied to the company. The case company identified its production problem and made the actions on the production process improvement with the good result of product quality improvement. This research can provide a reference for manufacturing companies to apply SPC methods and statistical tools to production process control for product quality improvement.

**Keywords:** Production process control · Process capability analysis · Quality improvement

## 1 Introduction

The quality of products has become an important factor to lead the rapid development of markets. However, defect products cannot be completely avoided due to many factors. Statistical process control (SPC) can apply control charts for monitoring processes, detecting changes, and controlling process quality [1].

Researchers have studied statistical process control. For example, Park *et al.* [1] studied the integration of automatic process control (APC) and SPC and developed an economic cost model to integrate APC and SPC. They used different controllers in the integrated systems and developed a long run expected cost for investigating the use of the different controllers.

Guerra, Sousa, and Nunes [2] made a case study on automating the inspection process of an automotive company by applying statistical process control for quality assurance.


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They aimed to make more robust and effective quality assurance procedures. They made successful introduction of automation by SPC in final inspection process.

Sousa, Rodrigues, and Nunes [3] initially studied one potential critical variable in the pre-production phase by using control charts. They identified the main causes of variability in the production process of a mental part and reduced the percentage of defective parts.

Ng [4] discussed the use of SPC control charts as a project management tool. They discussed the benefits of using control charts in the situations of system implementation, service acceptance, and so on.

This paper proposes an approach for product quality improvement. The approach identifies and analyzes the production problem and applies statistical process control to inspect and correct the production process to solve the problem. A case study is made to a real manufacturing company.

## 2 Developed Approach

The SPC method include Xbar-R control charts and process capability analysis. Xbar-R control charts can be used to ensure information in determining whether a process can meet the requirements and can also be used to provide a basis for current decision-making during production such as when to find the causes of variation [5].

Process capability analysis determines whether a production process meet requirements. Actions for adjustment of a process according to the process capability include no action, action to adjust centering, action to reduce variability, and so on [5]. Process capability analysis can be applied to control production to eliminate particular causes of variation during a manufacturing process [5].

The approach proposed for product quality improvement is based on problem analysis and the application of control chart analysis and process capability analysis. It includes the following steps.

**Step 1.** Problem identification. Analyze company's production process to find the problem in production. Form a quality improvement group that should include the director of process department or the quality department, the chief technologist, and quality analyzers.
**Step 2.** Problem analysis. Analyze the related products, parts, and processes to find the causes of the problem.
**Step 3.** SPC method determination. Determine SPC methods to be applied according to parts and equipment used in production. Collect the data of related production process.
**Step 4.** Production process analysis. Analyze the production process by the applications of control charts, process capability analysis, and so forth.
**Step 5.** Cause analysis. Analyze the production process with abnormality detected to find possible causes. Form measures for production process improvement.
**Step 6.** Problem solving. Make actions for improvement and analyze the results until satisfied results are achieved to solve the problem.

# 3 Application Case

## 3.1 Problem Identification

The production of type A oil cylinder by Shanxi Aerospace Tsinghua Equipment Co., Ltd was studied. The company analyzed the trial production of type A oil cylinder and found that there are many defect products and many shortages in manufacturing technology of this type oil cylinder. Test indexes could not meet the technical requirements. Therefore, quality improvement was needed.

The company established a quality improvement project team. There are eight project team members, including one senior engineer, four engineers, one quality engineer, and two senior technicians. Their responsibilities are the director of the process department of the company, chief technologist, quality analyzer, technician, and operator.

## 3.2 Problem Analysis

The central body is the key part of model A oil cylinder. It is an assembly and welding part and the dimensional accuracy of the key part is high. It is difficult to mill in CNC machine tools and it is easy to produce unqualified products.

It was found that there were many flaws in the central body. The technical requirement for the unqualified ratio of the central body was less than 6%. However, the unqualified ratio of the actual parts was 15%, far exceeding the technical requirement. It was found that the symmetry degree of support ear middle groove of the central body was out of the tolerance range.

## 3.3 SPC Method Determination

Based on the analyses, the quality improvement project team considered to apply SPC methods to detect abnormality in the production process of manufacturing the part. The project team selected Xbar-R control charts and process capability analysis.

Although the products belong to the scope of small size and multiple batch, the differences between the samples studied are small. In order to collect data to show product quality characteristics, the metrological data were collected. The project team collected the data of symmetry degree of support ear middle groove for analysis, extracted the data of 5 workers, 6 data were randomly selected from each worker, and 30 data were collected. Sample data of symmetry degree of support ear middle groove are displayed in Table 1.

## 3.4 Production Analysis

The range of symmetry degree of support ear middle groove is 0–0.03 mm. Two sets of data are used for a group to draw Xbar-R control charts according to the requirements of design and process. The data analysis is made by applying statistical software Minitab [6], the control charts are shown in Fig. 1.

From the Xbar control chart, the diagram does not show a lack of control in the production system. As can be seen from the figure of the R control chart that no points

**Table 1.** Sample data (before improvement).

| No. | Operator 1 | Operator 2 | Operator 3 | Operator 4 | Operator 5 |
|---|---|---|---|---|---|
| 1 | 0.020 | 0.006 | 0.018 | 0.018 | 0.028 |
| 2 | 0.007 | 0.009 | 0.036 | 0.026 | 0.005 |
| 3 | 0.023 | 0.022 | 0.014 | 0.030 | 0.025 |
| 4 | 0.012 | 0.033 | 0.015 | 0.014 | 0.028 |
| 5 | 0.014 | 0.011 | 0.013 | 0.028 | 0.025 |
| 6 | 0.017 | 0.013 | 0.021 | 0.026 | 0.014 |

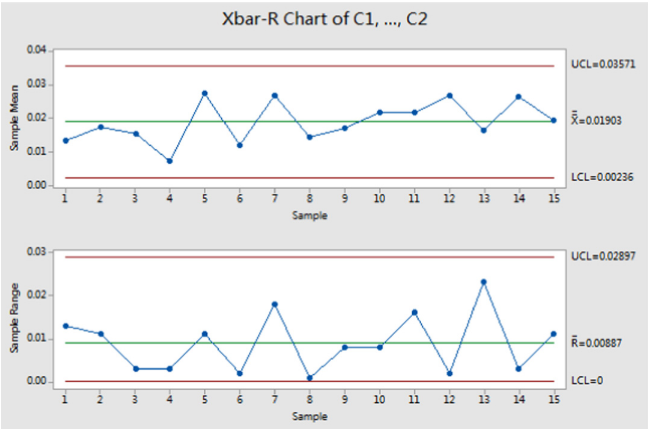


**Fig. 1.** Xbar-R control charts (before improvement).

are outside the scope of the lower and upper limits of LCL and UCL and that the points in these ranges are randomly displayed.

The project team also made process capability analysis. The process capability chart is shown in Fig. 2. Two of them are in a group. The tolerance range by LSL and USL is 0.03mm. Some parts are not in the range as shown in the figure. Cp = 0.63 and Cp < 0.67 in the figure. This indicates that the unqualified product ratio in the production process exceeded the requirement.

### 3.5 Cause Analysis

The project team inspect the production process and found that positioning of tooling mandrel and product inner hole lacks inaccuracy because of the role of gravity. The project team made the testing of X axis, Y axis, and Z axis for the repeated positioning accuracy of the machine tool.

The repeated positioning of X axis and Z axis is accurate with an error less than 0.02 mm. The error of the repeated positioning of Y axis is large, exceeding 0.02 mm. This might cause processing inaccuracy and produce product flaws.

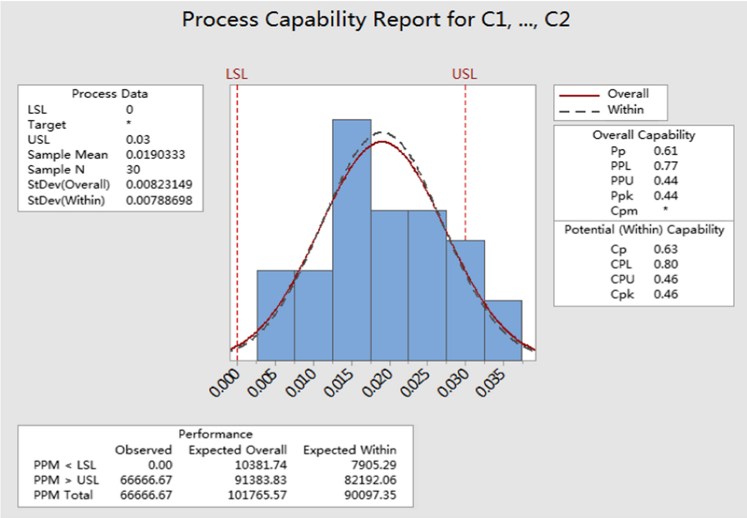


**Fig. 2.** Process capability chart (before improvement).

### 3.6 Problem Solving

The company developed the following measures and made actions for production process improvement. Better tooling mandrels were adopted, which could make a smaller error in positioning. The company also adjusted the parameter compensation of the machine tool in Y axis. The repeated positioning accuracy of Y axis was improved and reached the requirement.

The project team carried out spot check and collected the sample data of symmetry degree of support ear middle groove after the implementation of the improvement actions. The project team collected 30 samples. The sample data are displayed in Table 2.

The Xbar-R control charts are drawn for two of a group, as shown in Fig. 3. There is no data beyond the limits and these data points show random mode. This control chart shows that the process is controlled. It can be observed from the figure of R control chart that there is no data beyond the boundary and these data are evenly distributed on both sides of the center line, indicating that the process is controlled.

**Table 2.** Sample data (after improvement).

| No. | Operator 1 | Operator 2 | Operator 3 | No. | Operator 1 | Operator 2 | Operator 3 |
|---|---|---|---|---|---|---|---|
| 1 | 0.013 | 0.016 | 0.013 | 6 | 0.016 | 0.020 | 0.016 |
| 2 | 0.020 | 0.021 | 0.024 | 7 | 0.022 | 0.024 | 0.024 |
| 3 | 0.021 | 0.023 | 0.013 | 8 | 0.017 | 0.017 | 0.016 |
| 4 | 0.014 | 0.012 | 0.022 | 9 | 0.021 | 0.023 | 0.023 |
| 5 | 0.024 | 0.016 | 0.017 | 10 | 0.019 | 0.016 | 0.017 |

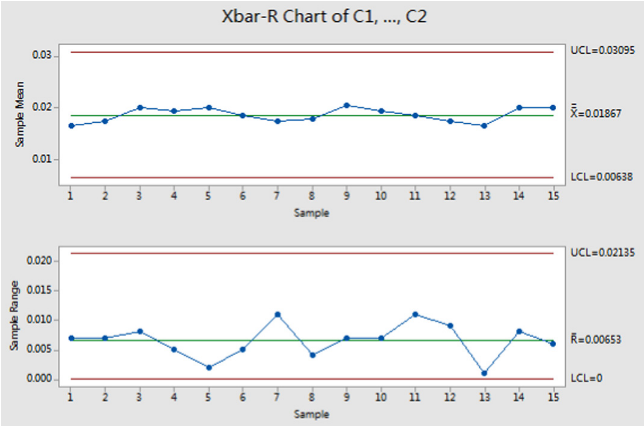


**Fig. 3.** Xbar-R control charts (after improvement).

The process capability chart are also drawn from the collected sample data, two for a group. The process capability chart is illustrated in Fig. 4. The tolerance range by LSL and USL is 0.03 mm. All parts are in the range as shown in the figure. Cp = 0.98, indicating that the process capability index of the production process is close to 1. The production process capability was improved.

The company produced 200 parts with 11 unqualified parts after the improvement. The ratio of unqualified parts was 5.5%, within the range of the requirement. The problem was solved.

The company set the tolerance range for manufacturing parts in the production process. When applied the SPC methods, the abnormality was found with parts outside the

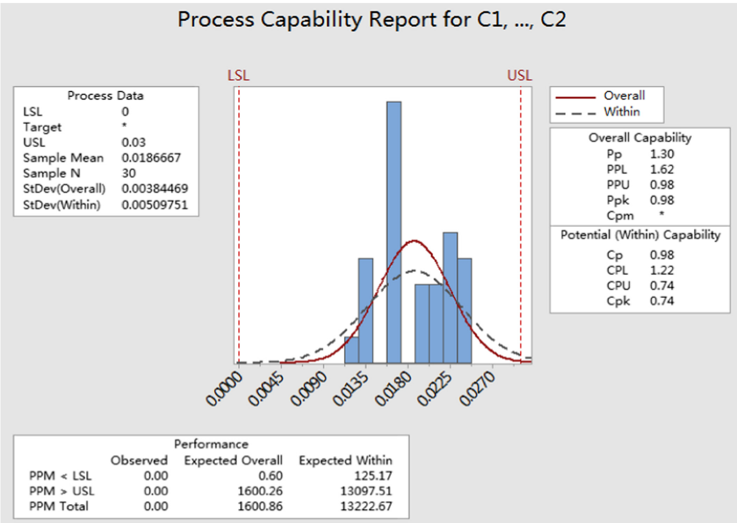


**Fig. 4.** Process capability chart (after improvement).

range of LSL and USL even though without parts outside the scope of LCL and UCL. Therefore, abnormality identification should not be made only by Xbar-R control charts. More SPC tools should be applied to identify abnormality.

## 4 Conclusion

Production process control and product quality improvement are important issues. This paper proposes an approach based on problem analysis and SPC application for product quality improvement. A case study is provided. The case company identified and analyzed the problem, applied Xbar-R control charts and process capability analysis, analyzed the causes of abnormality in the production process, formed measures, and took actions to solve the problem with the satisfaction of the requirement for the ratio of unqualified products.

The research can provide a reference for companies to apply SPC methods and statistical tools for production process control to improve product quality. The presented approach can help companies to solve their production quality problems step by step through identifying the defects from products in their manufacturing processes.

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## References

1. Park, M., Kim, J., Jeong, M., Hamouda, A., Al-Khalifa, K., Elsayed, E.: Economic cost models of integrated APC controlled SPC charts. Int. J. Prod. Res. **50**, 3936–3955 (2012)
2. Guerra, L., Sousa, S.D., Nunes, E.P.: Statistical process control automation in the final inspection process: an industrial case study. In: Proceedings of the 2016 IEEE IEEM, pp. 876–880 (2016)
3. Sousa, S., Rodrigues, N., Nunes, E.: Application of SPC and quality tools for process improvement. Procedia Manuf. **11**, 1215–1222 (2017)
4. Ng, J.J.: Statistical process control chart as a project management tool. IEEE Eng. Manage. Rev. **46**, 26–28 (2018)
5. Grant, E.L., Leavenworth, R.S.: Statistical quality control. 1st edn. McGraw-Hill Education (Asia) Co., China Tsinghua University Press, Beijing (2002)
6. Minitab Homepage. http://www.minitab.com/zh-cn. Accessed Sep 2020