

ANALYSIS AND IMPLEMENTATION OF CONTROL CHARTS FOR QUALITY IMPROVEMENT AND PRECISION ASSESSMENT IN MANUFACTURING PROCESSES

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Abstract: This paper analyzes and implements control charts as a tool for improving quality in manufacturing processes. Through the analysis of statistical methods for monitoring variations in production, the paper investigates how control charts are used to identify and eliminate sources of problems that affect product accuracy. Based on the collected data on product quality measures, the control chart method is applied to assess process stability and detect potential deviations from established standards. The research includes the formation of appropriate control charts, process accuracy analysis, and suggestions for improving the manufacturing process through the application of statistical tools.

Key words: control charts, process quality, manufacturing process, accuracy assessment, process stability

1. INTRODUCTION

Production processes often involve various variations that can significantly impact the quality of the final product. To ensure quality consistency, it is important to monitor these variations and take corrective actions in a timely manner. One of the most effective tools for this is the use of control charts, which enable real-time monitoring of process stability. Control charts help identify undesirable variations and allow the recognition of problem causes, contributing to the improvement of product accuracy and quality. In this paper, we will use control charts to analyze the accuracy of the production process, with a particular focus on implementing corrections that can enhance precision and reduce the number of defective products.

2. METHODOLOGY

For the analysis of the production process quality, we will use the control chart method, specifically the X-bar (average) and R (range) charts. Based on samples of size $n=10$, we will analyze the measurement of product quality characteristics during sampling periods. The data for analysis were obtained from actual measurements of the production process, where the tolerance value of the measured parameter was set to $T=155 \pm 0.06$.

- 2.1. **Data Collection:** The first step is to collect samples, where measurements were taken at regular intervals during the production process. The samples are provided in a table that contains the values of the measured characteristic and the corresponding range (R) for each sample.
- 2.2. **Calculation of Basic Statistical Parameters:** It is necessary to calculate the average values (X-bar) and range (R) for each sample, and then calculate the overall average and range for the entire series of samples.
- 2.3. **Creation of Control Charts:** Based on the calculated parameters, we will create control charts that include the upper and lower control limits (UCL and LCL). These limits are used to monitor and assess the stability of the process over time.
- 2.4. **Process Stability Evaluation:** The analysis of the samples in relation to the control limits will help identify potential irregularities or unacceptable variations.

The formulas used for calculating the control limits are based on standard statistical parameters for $n=10$.

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3. PROCESS ACCURACY TESTING

Process accuracy testing, in the context of implementing control charts, plays a key role in improving the quality and precision of manufacturing processes. Process accuracy refers to the system's ability to produce products in accordance with specific requirements and standards, with minimal deviations from desired values. This part of the analysis focuses on identifying and assessing sources of errors in the process, as well as applying appropriate methods for their detection and minimization.

3.1. Defining Process Accuracy

Accuracy is typically defined as the ability of a process to produce products within specified tolerances, with minimal variation and errors. In manufacturing processes, accuracy is often measured against target values or product specifications. Errors in the process can be caused by various factors, such as machine inaccuracy, human error, variable raw materials, or improper use of tools.

3.2. Methods for Testing Accuracy

Accuracy testing can be conducted using various methodologies and statistical techniques. The classical approach involves the use of control charts, which allow real-time monitoring of variations in the process. Control charts can reveal whether the process is functioning within the set accuracy limits or whether corrective actions are necessary.

In accuracy testing, the following methods are commonly used:

- **Analysis of mean and standard deviation:** These metrics help identify systematic errors and variations in the process.
- **Hypothesis testing:** Used for statistical verification of whether the differences between actual values and desired targets are statistically significant.
- **Error distribution assessment:** Analyzing the distribution of errors helps understand the nature of deviations and assess whether errors are random or caused by specific factor changes.

3.3. Implementation of Control Charts

Control charts, such as X-bar and R-charts or np-charts, play a crucial role in testing process accuracy. A control chart helps monitor changes in the process over time, enabling the detection of undesirable variations that may affect product accuracy. Analyzing these charts can identify points in the process where control limits are exceeded, allowing for corrective actions before serious errors or non-compliance with specific requirements occur.

3.4. Measurement Precision Assessment

Measurement precision is critical for the reliability of accuracy testing. In manufacturing processes, measurement precision refers to the repeatability and consistency of measurement results. Inaccuracies in measuring instruments can lead to incorrect conclusions about the process's accuracy. In this context, the use of calibrated and validated measuring instruments is recommended, along with periodic checks of measurement accuracy.

3.5. Corrective Actions and Process Improvement

Once deviations from desired accuracy are detected, corrective actions must be implemented. These actions may include machine adjustments, operator training, improvement of quality control, or changes in the manufacturing process. Continuous accuracy testing combined with control charts enables the identification of when a process stops being stable and precise, providing a timeframe for implementing improvements and bringing the process back within the desired accuracy range.

In conclusion, process accuracy testing is a key element in maintaining and improving production quality. The application of appropriate statistical methods and control charts helps in early problem detection and allows for timely corrective actions. This way, the process can remain

stable, precise, and in compliance with specifications, contributing to overall improvements in quality and manufacturing efficiency.

4. RESULTS

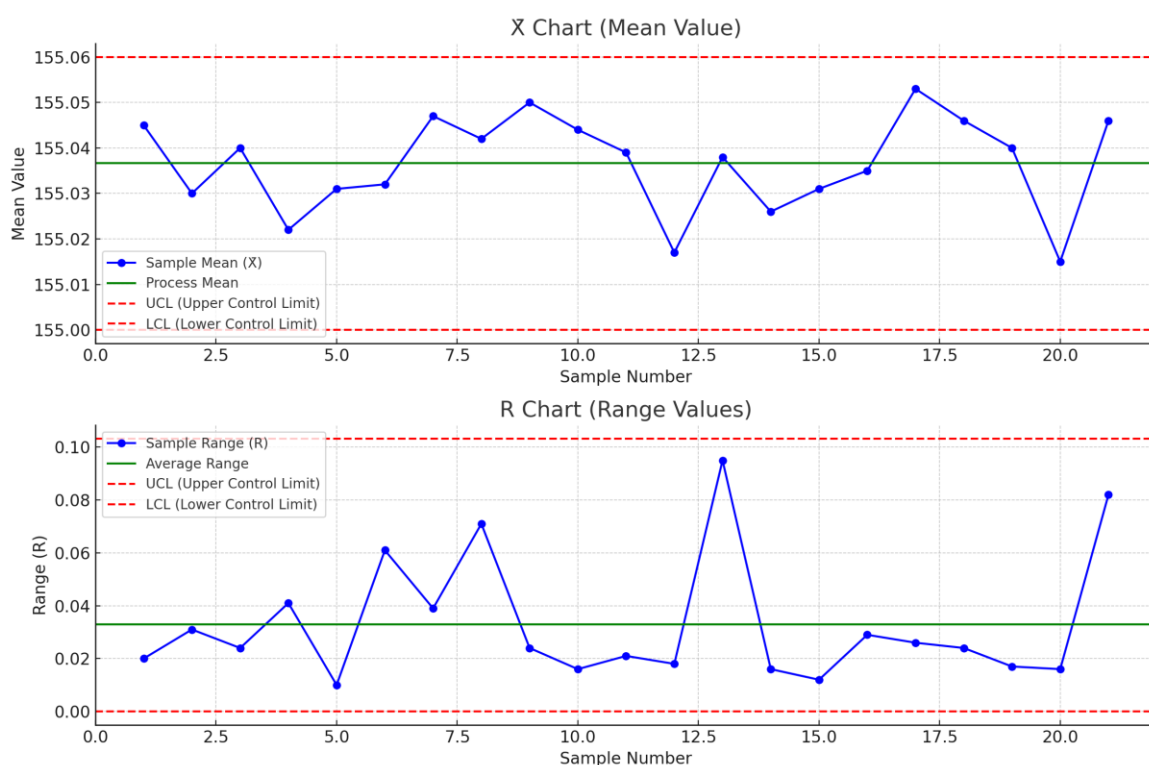
By monitoring the production process, the quality characteristic x (e.g., dimension, mass, or another relevant physical property) is measured. Samples are taken at specific time intervals, with the number of parts in each sample being $n=10$. All results are expressed in millimeters (mm) to ensure consistency in the analysis.

The tolerance of the measured characteristic is $T=155\text{ mm}\pm 0.06\text{ mm}$

All measurement results (sample means $\bar{x}$) and ranges R are expressed in millimeters (mm):

Table 1 -Table with measurement results

Sample No	$\bar{x}$	R	Sample No	$\bar{x}$	R	Sample No	$\bar{x}$	R
1.	155,045	0,020	8.	155,042	0,071	15.	155,031	0,012
2.	155,030	0,031	9.	155,050	0,024	16.	155,035	0,029
3.	155,040	0,024	10.	155,044	0,016	17.	155,053	0,026
4.	155,022	0,041	11.	155,039	0,021	18.	155,046	0,024
5.	155,031	0,010	12.	155,017	0,018	19.	155,040	0,017
6.	155,032	0,061	13.	155,038	0,095	20.	155,015	0,016
7.	155,047	0,039	14.	155,026	0,016	21.	155,046	0,082



Based on the analysis of the collected data and the creation of control charts, the results show that most samples remain within the control limits, indicating the stability of the production process. However, several samples show signals of approaching the limits, which may suggest the need for further investigations or adjustments in production. Based on the calculated statistical parameters, corrective actions have been proposed, including equipment checks and operator training.

5. DISCUSSION

Control charts are a powerful tool in the analysis of production processes because they allow for the visualization of variations in the process. When the data is within the control limits, it suggests that the process is stable and under control. If the data goes beyond the limits, it indicates potential problems in the process that may require intervention. In our case, controls are carried out for the quality parameter characteristic ($T=155\pm0.06$), meaning that any sample outside this range will signal the need for adjustment. By analyzing the measurement results from the table, we can see that the variations in the range (R) are relatively small, which may suggest that the process is stable, but further analysis is needed to ensure accuracy. Additionally, it is necessary to verify whether the changes in the measurement values are caused by external or internal factors and whether all factors in the process are optimized to reduce deviations.

6. CONCLUSION

The research paper analyzes the principles of control charts as a key tool for improving quality and assessing precision in manufacturing processes. Control charts enable the identification of variations in processes, which helps in detecting potential problems and imperfections that may negatively impact product quality. By analyzing and implementing appropriate control charts in the manufacturing environment, it is possible not only to improve product quality but also to optimize overall production processes, reduce costs, and increase efficiency. The use of control charts allows organizations to proactively manage variations in the process, contributing to the stability of production systems and the achievement of high-quality standards.

Additionally, the implementation of control charts enables continuous monitoring of production parameters, leading to better decisions regarding necessary corrective actions and improvements. Given the dynamics of modern markets and competition, the application of control charts becomes an essential element in strategies for sustainability and long-term business competitiveness.

For future research, a more detailed analysis of different types of control charts and their applications in specific industries is recommended, with a particular focus on digitalization and real-time data collection. Further research in this field could contribute to the improvement of methodologies for monitoring and controlling production processes, as well as the integration of new technologies in the context of Industry 4.0.

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