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OPTIMALIZACIJA I PRIMENA KONTROLNIH KARATA ZA POBOLJŠANJE KVALITETA I TAČNOSTI U PROIZVODNIM PROCESIMA

**OPTIMIZATION AND APPLICATION OF CONTROL CHARTS
FOR IMPROVING QUALITY AND ACCURACY
IN MANUFACTURING PROCESSES**

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Ovaj rad istražuje optimalizaciju i primenu kontrolnih karata kao način za unapređenje kvaliteta i preciznosti u proizvodnim procesima. Analizom statističkih metoda za praćenje varijacija u proizvodnji, ispituje se kako se kontrolne karte mogu koristiti za identifikovanje i rešavanje problema koji utiču na tačnost proizvoda. Korišćenjem podataka o metrici kvaliteta proizvoda, rad pokazuje kako kontrolne karte procenjuju stabilnost procesa i identifikuju potencijalne devijacije od postavljenih standarda. Istraživanje obuhvata izradu odgovarajućih kontrolnih karata, analizu tačnosti procesa i preporuke za poboljšanje proizvodnih procesa kroz upotrebu statističkih alata.

This paper explores the optimization and application of control charts as a means to enhance quality and precision in manufacturing processes. By analyzing statistical methods for tracking variations in production, it examines how control charts can be used to identify and resolve issues that impact product accuracy. Using data on product quality metrics, the paper demonstrates how control charts assess process stability and identify potential deviations from set standards. The research involves the creation of suitable control charts, an analysis of process accuracy, and recommendations for improving manufacturing processes through the use of statistical tools.

1. Introduction

Production processes often involve various variations that can significantly affect the quality of the final product. To ensure consistent quality, it is crucial to monitor these variations and implement corrective actions promptly. One of the most effective tools for this purpose is the use of control charts, which facilitate real-time monitoring of process stability. Control charts help detect undesirable variations and identify their root causes, ultimately contributing to improvements in product accuracy and quality. This paper explores the optimization and application of control charts to analyze the accuracy of manufacturing processes, with a focus on implementing corrective measures to enhance precision and minimize defective products.

2. Methodology

For the analysis of the production process quality, will be use the control chart method, specifically the X-bar (average) and R (range) charts. Based on samples of size $n=12$, will be analyzed 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 $T=150 \pm 0.05$.

- 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, will be created 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 $n=12$.

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

Table 1 presents data related to the measurement of the quality characteristic \bar{x} during the production process. Samples were taken at specific time intervals, with the number of parts in each sample being $n = 12$.

Table 1. Table with measurement results

| Sample No | \bar{x} [mm] | R [mm] | Sample No | \bar{x} [mm] | R [mm] | Sample No | \bar{x} [mm] | R [mm] |
|-----------|----------------|--------|-----------|----------------|--------|-----------|----------------|--------|
| 1. | 150,025 | 0,021 | 8. | 150,044 | 0,070 | 15. | 150,021 | 0,014 |
| 2. | 150,034 | 0,032 | 9. | 150,020 | 0,023 | 16. | 150,035 | 0,073 |
| 3. | 150,010 | 0,025 | 10. | 150,064 | 0,017 | 17. | 150,053 | 0,028 |
| 4. | 150,072 | 0,043 | 11. | 150,029 | 0,029 | 18. | 150,036 | 0,044 |
| 5. | 150,021 | 0,017 | 12. | 150,087 | 0,012 | 19. | 150,040 | 0,027 |
| 6. | 150,035 | 0,051 | 13. | 150,048 | 0,090 | 20. | 150,025 | 0,018 |
| 7. | 150,049 | 0,041 | 14. | 150,036 | 0,018 | 21. | 150,076 | 0,022 |

All results are expressed in millimeters (mm) to ensure consistency in the analysis.

The tolerance of the measured values is $T = 150 \text{ mm} \pm 0.06 \text{ mm}$.

Table 1 shows the sample mean values and the corresponding ranges (R) in millimeters.

After this table, diagrams are presented that visually illustrate the changes in the sample mean values (\bar{x}) and ranges (R) across different samples. These diagrams facilitate an easier analysis of trends and variations in the production process.

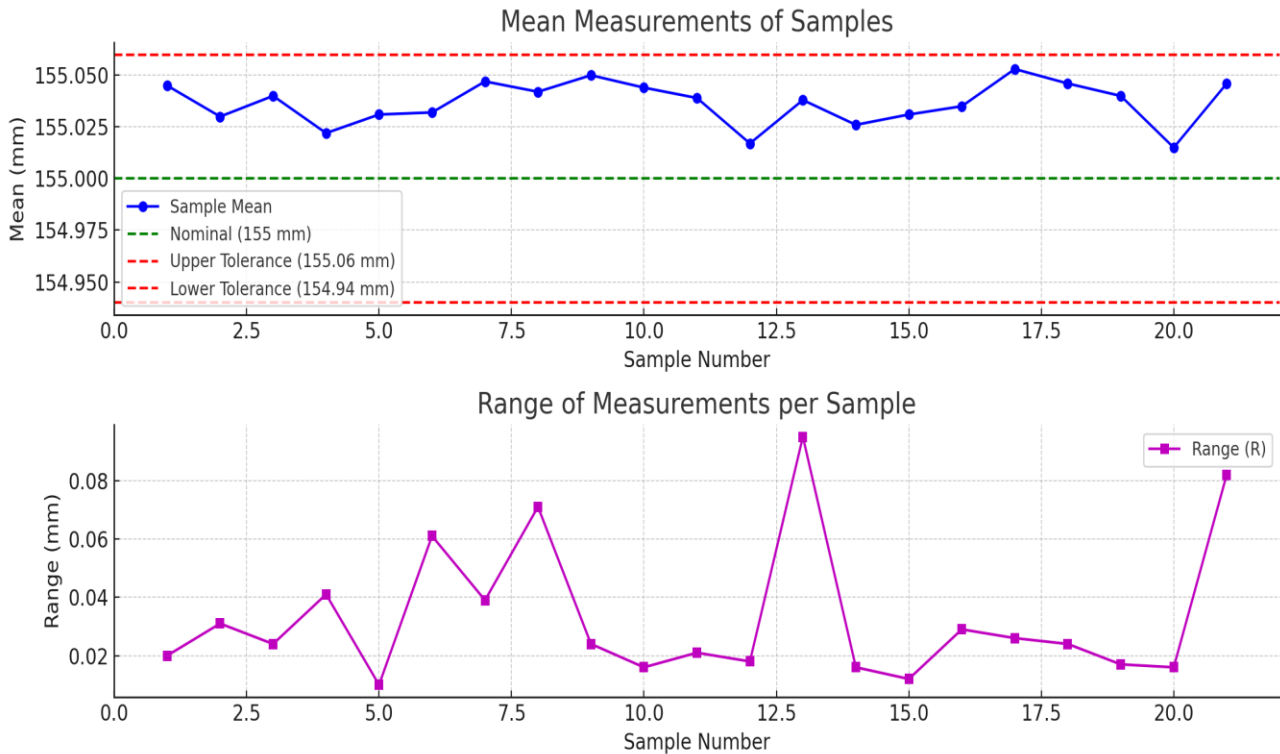


Diagram of changes in sample mean values (\bar{x}) and ranges (R)

Data analysis

Mean values of samples:

- All samples are close to the nominal value (155 mm).
- No sample exceeds the tolerance limits (154.94 mm – 155.06 mm), indicating a stable process.
- There is slight variation among the samples, but no significant deviations.

Ranges (R):

- Range values vary between 0.01 mm and 0.095 mm.
- The largest range is in sample 13 (0.095 mm), indicating greater internal variations.
- Overall, the ranges are low, suggesting consistency within the samples.

5. Discussion

Data collected from the production process allow for the assessment of the quality and stability of the measured characteristic (x). By analyzing the sample means and ranges (R), can be determined whether the process remains within acceptable tolerances and identify potential variations that could indicate deviations from stability.

Analysis of sample means

- 1. Consistency with the nominal value:** The sample means are closely grouped around the nominal value of 150 mm, with no significant deviations. This indicates a high level of accuracy in the production process.
- 2. Compliance with tolerances:** The tolerance for the characteristic is set at 150 mm \pm 0.06 mm (149.94 mm to 150.06 mm). All sample means fall within this range, confirming that the process is functioning within the defined quality standards.
- 3. Process stability:** The results show no extreme deviations or significant shifts, suggesting that the process remains stable over time.

Analysis of Range (R) Values

- 1. Variation among samples:** The ranges vary from 0.012 mm to 0.095 mm, indicating some level of dispersion in the measurements.
- 2. Largest recorded deviation:** The largest range value (0.095 mm) was observed in sample 13. This suggests that this sample may have experienced slightly higher internal variation, likely due to minor variations in the process or inconsistencies in measurement.
- 3. General consistency:** Most ranges remain relatively low, indicating that the variation within each sample is controlled and does not pose a significant issue.

General Observations and Recommendations

- The data suggests that the production process is well-controlled, as all sample means fall within the defined tolerances.
- Although there are small variations in the range values, they do not significantly affect the overall quality.
- The presence of slightly higher range values in some samples could indicate the need for further investigation to ensure that process parameters remain optimized.
- Monitoring should continue to detect any future trends that may indicate deviations, ensuring long-term stability and quality assurance.

The evaluation of the sample means and ranges confirms that the production process is stable and functions within the defined tolerances. The observed variations do not indicate immediate problems but highlight the importance of continuous monitoring and quality control to maintain consistency in results. Reducing factors contributing to variations will help preserve the reliability of the process and the quality of the final product.

6. Conclusion

This research paper examines the role of control charts as a crucial tool for enhancing quality and assessing accuracy in manufacturing processes. Control charts provide a means of detecting variations within processes, allowing for the identification of potential issues that could adversely affect product quality. By integrating appropriate control charts into manufacturing environments, organizations can not only improve product quality but also streamline production processes, reduce costs, and enhance efficiency. The application of control charts allows businesses to proactively manage process variations, ensuring stability in production systems and supporting the achievement of high-quality standards.

Furthermore, the adoption of control charts facilitates continuous monitoring of production parameters, enabling more informed decisions regarding corrective actions and improvements. In the face of rapidly evolving markets and increasing competition, the use of control charts has become a vital component of strategies aimed at ensuring sustainability and long-term business competitiveness.

Looking ahead, future research could focus on a more in-depth analysis of various types of control charts and their specific applications across different industries, with particular emphasis on the role of digitalization and real-time data collection. Continued exploration in this area could further refine methodologies for monitoring and controlling production processes, while also exploring the integration of emerging technologies in the context of Industry 4.0.

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