UNIT III

STATISTICAL PROCESS CONTROL

Meaning and significance of statistical process control (SPC) – construction of control charts for variables and attributes. Process capability – Meaning, significance and measurement – Six sigma - concepts of process capability. Reliability concepts – Definitions, reliability in series and parallel, product life characteristics curve. Total productive maintenance (TMP), Tero Technology.

STATISTICAL PROCESS CONTROL

Statistical process control (SPC) is defined as the use of statistical techniques to control a process or production method. SPC tools and procedures can help you monitor process behavior, discover issues in internal systems, and find solutions for production issues. Statistical process control is often used interchangeably with statistical quality control (SQC)

Core Principles of Statistical Process Control

Statistical Process Control (SPC) is founded on a set of fundamental principles that guide effective monitoring and improvement of processes.

Understanding Variation

All processes exhibit variation. SPC enables differentiation between:

- **Common cause variation**: Natural, inherent variability present in a stable process
- **Special cause variation**: Unusual variation caused by identifiable factors requiring investigation

Recognizing these two types of variation prevents unnecessary adjustments and supports systematic improvement.

Process Stability

A process is considered **stable** when it operates consistently over time within predictable limits. Stable processes allow reliable forecasting of performance and form the foundation for capability improvement.

Continuous Improvement

SPC is not limited to maintaining current performance levels. It acts as a continuous improvement tool by identifying opportunities for reducing variation and enhancing process efficiency.

Prevention over Detection

SPC emphasizes **real-time monitoring** of processes to prevent defects rather than relying solely on post-production inspection. Early detection of variation minimizes downstream quality issues.

Data-Driven Decision Making

SPC replaces intuition-based decisions with statistical evidence, enabling objective analysis and informed managerial actions.

Advantages of Implementing SPC

The primary objective of SPC is to monitor, control, and improve process performance over time. However, its benefits extend across multiple organizational dimensions.

Reduced Variability

SPC identifies root causes of variation and facilitates corrective action, resulting in consistent product or service quality.

Increased Productivity

By minimizing rework, scrap, and downtime, SPC improves throughput and overall operational efficiency.

Cost Reduction

Lower defect rates and waste reduction lead to significant cost savings in materials, labor, and warranty expenses.

Improved Customer Satisfaction

Consistent quality enhances customer confidence, reduces complaints, and strengthens brand reputation.

Proactive Problem Solving

SPC shifts organizations from reactive problem-solving to proactive process management by identifying issues before they escalate.

Control Charts: The Core Tool of SPC

Control charts provide a graphical representation of process behavior over time and are central to SPC implementation.

Types of Control Charts and Their Applications

Variable Control Charts

Used for **continuous data** such as dimensions, weight, temperature, or time.

- **$\bar{X}$ and R Charts**
  Suitable when data is collected in rational subgroups and variability within subgroups can be assessed.
- **Individuals and Moving Range (I–MR) Charts**
  Used when subgrouping is not feasible or data is collected one observation at a time.

Attribute Control Charts

Used for **discrete data**, such as defect counts or pass/fail outcomes.

- **P and NP Charts**
  Monitor the proportion or number of defective units.
- **C and U Charts**

Track the number of defects per unit or per area of opportunity.

Selecting the appropriate chart depends on data type, sample size, and process characteristics.

Interpreting Control Charts

Effective interpretation is essential for extracting meaningful insights from SPC charts.

Control Limits

Control limits are typically set at **±3 standard deviations** from the process mean. Points outside these limits indicate special cause variation.

Trends

Seven or more consecutive points moving upward or downward may signal a process shift.

Patterns

Recurring cycles, alternating patterns, or sudden level changes may indicate equipment issues, environmental effects, or procedural changes.

Out-of-Control Conditions

Signals include:

- Points beyond control limits
- Runs of points on one side of the centerline
- Non-random patterns

Early identification of such signals prevents large-scale quality failures.

Common Pitfalls in Control Chart Analysis

Overreaction to Normal Variation

Adjusting a stable process unnecessarily increases variability and reduces performance.

Ignoring Subtle Trends

Gradual shifts within control limits may indicate early-stage process deterioration.

Confusing Control Limits with Specification Limits

Control limits reflect process behavior, while specification limits represent customer or design requirements.

Incorrect Chart Selection

Using inappropriate charts for the data type leads to misleading conclusions.

Implementing Statistical Process Control

Successful SPC implementation requires both technical competence and organizational readiness.

Organizational Preparation

- **Management Commitment**: Leadership support is essential for sustained SPC success

- **Employee Training**: Personnel must understand SPC concepts, tools, and purpose
- **Process Selection**: Focus initially on high-impact or high-risk processes
- **Data Infrastructure**: Reliable and timely data collection systems are critical

Data Collection and Analysis

- **Sampling Strategy**: Define suitable sampling frequency and method
- **Measurement Systems Analysis (MSA)**: Ensure measurement accuracy and consistency
- **Data Integrity**: Maintain accurate and unbiased data recording
- **Statistical Analysis**: Apply appropriate SPC techniques based on data characteristics

SPC Data Analysis Flow

1. Define measurement parameters
2. Conduct MSA
3. Collect process data
4. Enter data into SPC software
5. Generate control charts
6. Interpret results and take action

Sustaining SPC as a Quality Culture

Long-term success depends on embedding SPC into daily operations.

Continuous Training

Regular skill refreshment ensures consistent and correct application of SPC tools.

Periodic Review

Ongoing evaluation ensures relevance of metrics, control limits, and improvement goals.

Alignment with Business Objectives

SPC initiatives should support key performance indicators and strategic goals.

Recognition and Motivation

Acknowledging improvement efforts reinforces employee engagement and ownership.

Advanced Statistical Process Control Techniques

Multivariate Statistical Process Control (MSPC)

Modern processes often involve multiple interrelated variables. MSPC monitors these simultaneously.

- **Hotelling's T^2 Charts**: Monitor overall process stability across multiple variables
- **MEWMA Charts**: Detect small shifts in multivariate processes
- **Advantages**:
    - Reduced false alarms

- Better detection of interaction effects
- Comprehensive process monitoring

Short-Run SPC

Designed for high-mix, low-volume production environments.

- **Standardized Control Charts**
- **Group Charts**
- **Benefits**: Enables SPC application even with limited data availability

SPC in the Era of Industry 4.0

Digital transformation has significantly enhanced SPC capabilities.

Integration with IoT and Big Data

- **Real-time Monitoring** using sensors
- **Cloud-based SPC Systems** enabling global visibility
- **Predictive Quality Control** through advanced analytics

Artificial Intelligence and Machine Learning in SPC

- **Automated Pattern Recognition**
- **Predictive Maintenance**
- **Adaptive Control Limits** that adjust based on process behavior

AI-driven SPC systems improve accuracy, reduce response time, and enable proactive quality management.