Statistical Process Control on Aerospace Material and Shape

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Objective: Analyzing Critical Properties of Structural Material Shapes

The primary objective of this analysis is to evaluate the **tensile strength**, **thickness**, and **deflection** (Young's Modulus) of various aerospace structural shapes, including tapered, cylindrical, and rectangular designs. By applying SPC techniques like $\bar{X}$-R charts, EWMA, and CUSUM, we aim to identify process stability and areas that need improvement. The goal is to optimize these critical properties for enhanced performance and reliability.

Tensile Strength

Ensuring material resistance to breaking under tension.

Thickness

Maintaining consistent dimensions for structural integrity.

Deflection

Measuring material stiffness under load.

Material Type

Selecting appropriate materials for specific applications.

Problem Statement: Ensuring Structural Integrity

In aerospace, structural integrity is paramount. Variations in material properties and manufacturing processes can lead to deviations from design specifications, potentially causing catastrophic failures. By implementing SPC, we aim to address the critical problem of ensuring consistent quality and reliability in structural shapes. This includes monitoring tensile strength, thickness, and deflection to maintain high standards.

Process Variability

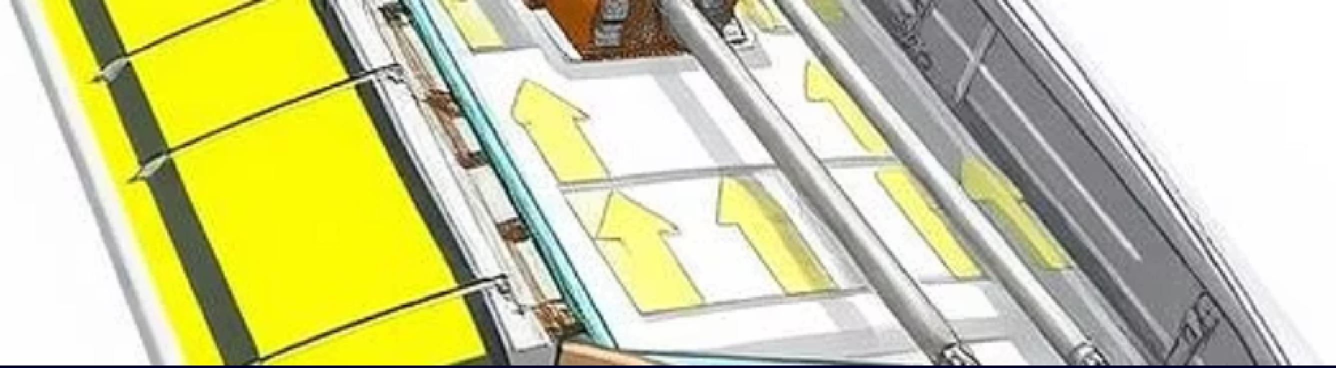
Reducing inconsistencies in manufacturing processes to enhance product quality.

Material Properties

Ensuring materials meet stringent specifications for aerospace use.

Structural Reliability

Enhancing the longevity and performance of aerospace components through rigorous monitoring.



Structural shape optimizes performance, weight, and aerodynamics, crucial for safety and efficiency.

The Importance of Structural Shape and Material in Aerospace Applications

The structural shape of aerospace components is critical for performance, weight, and aerodynamics, ensuring safety and efficiency. These shapes are designed to withstand specific loads and conditions, influencing strength, stability, and performance under extreme conditions.

1. **Aerodynamic Efficiency**

   Streamlined shapes minimize drag and maximize fuel efficiency.

2. **Weight Optimization**

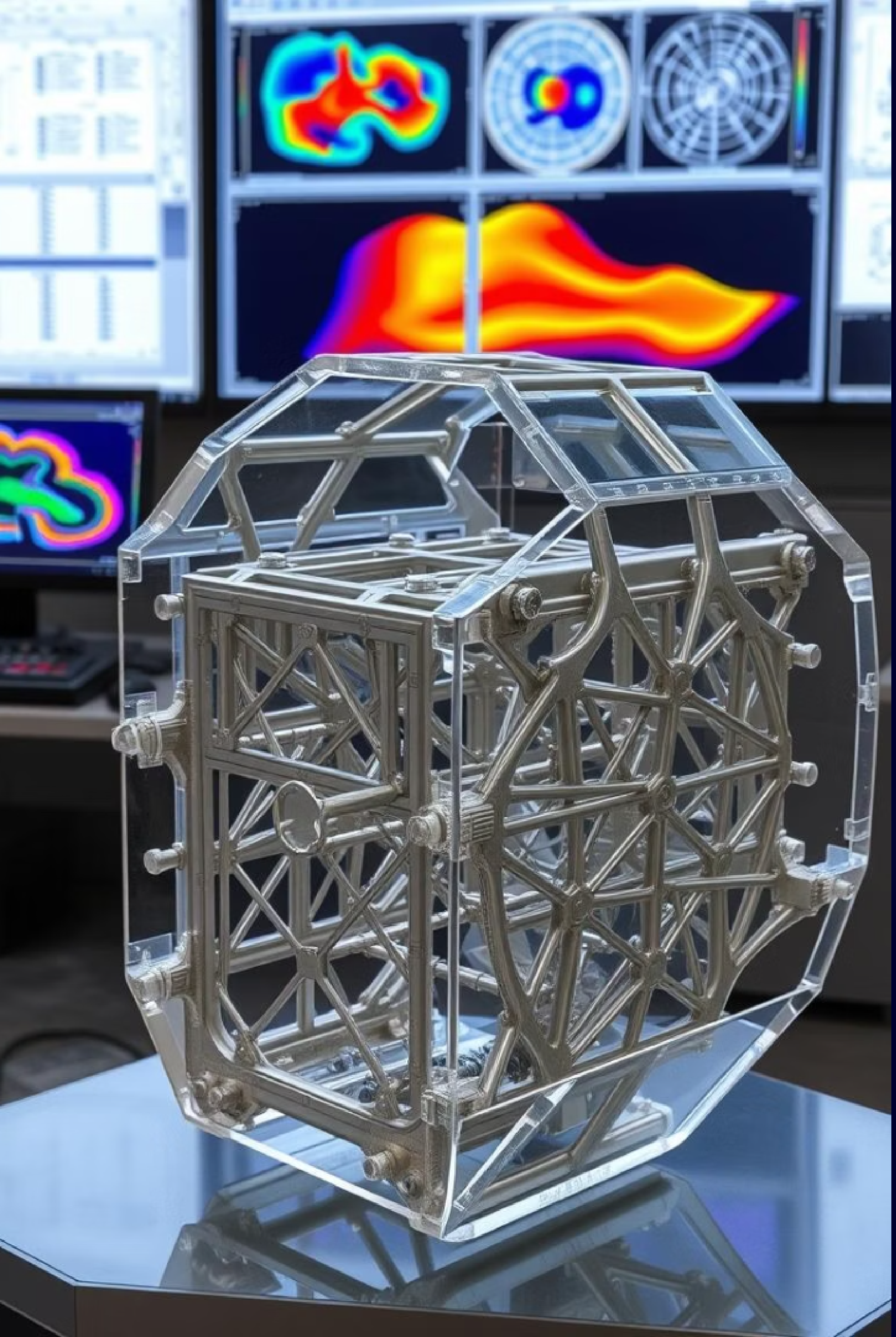
   Efficient designs minimize weight while preserving structural integrity.

3. **Load Distribution**

   Shapes distribute stress and strain evenly.

4. **Material Selection**

   Materials enhance strength and durability.



Data Overview: Parameters and Shapes

The data includes measurements of tensile strength, thickness, and deflection for different structural shapes like tapered, cylindrical, and rectangular. These parameters are essential for assessing process stability and identifying sources of variation. Accurate data is critical for effective SPC implementation.

Tensile , Yield Strength , Young's modulus

Measured in PSI, indicating the material's breaking point.

Design Shape

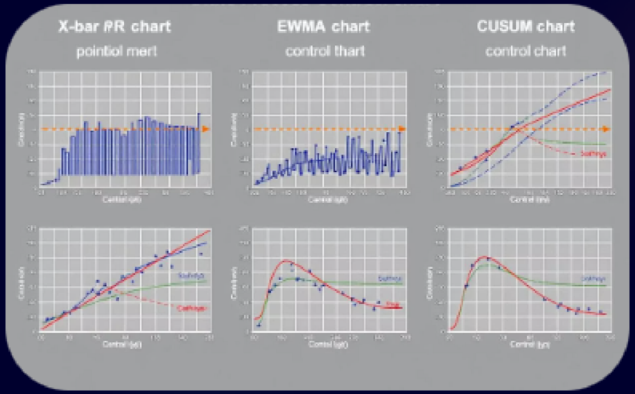
Tapered, Rectangle, Clyindrical

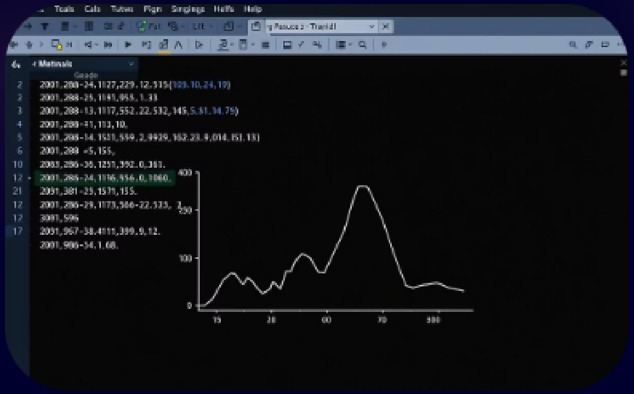
Material Type

Including Aluminum, Carbon Fiber, and Titanium.

Methodology: Applying SPC Techniques

Our methodology involves applying $\bar{X}$-R charts, EWMA, and CUSUM to the collected data.





Data Collection

Gathering tensile strength, thickness, and deflection measurements.

Chart Construction

Creating $\bar{X}$-R, EWMA, and CUSUM charts for design material and shape.

Analysis

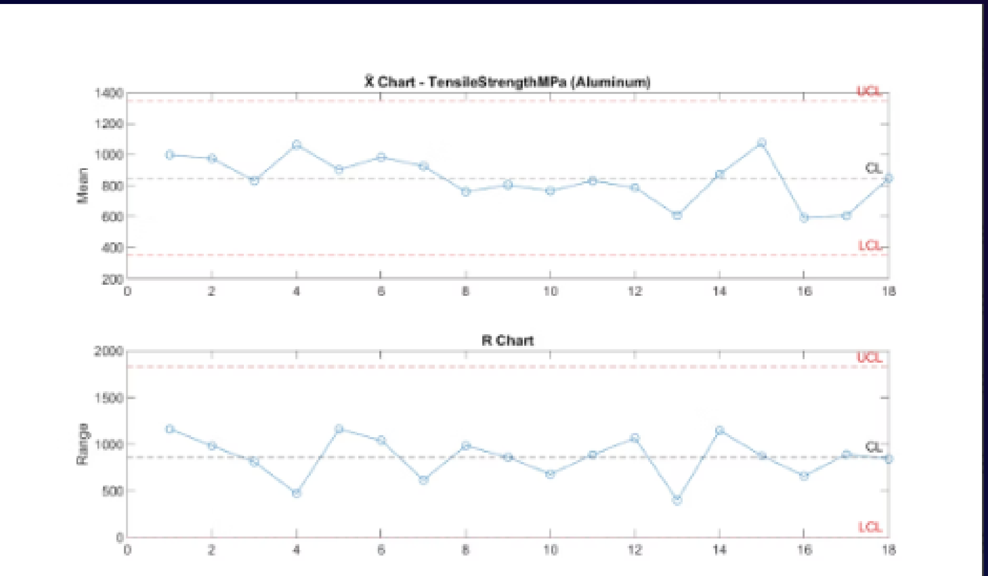
Analyzing process stability and identifying sources of variation using MATLAB.

Improvement

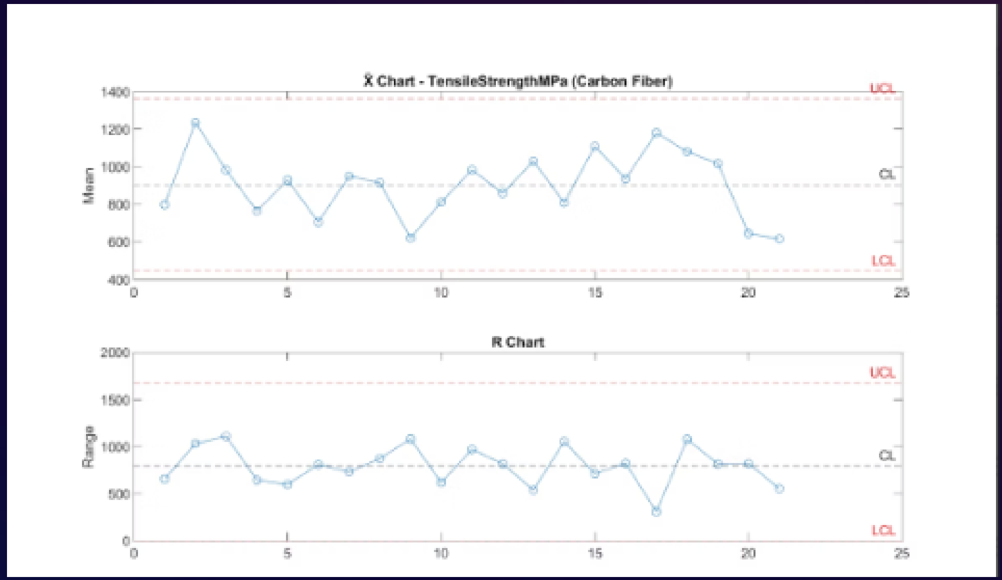
Integrating multiple design focuses to enhance product quality.

X-R Chart Analysis: Tensile Strength

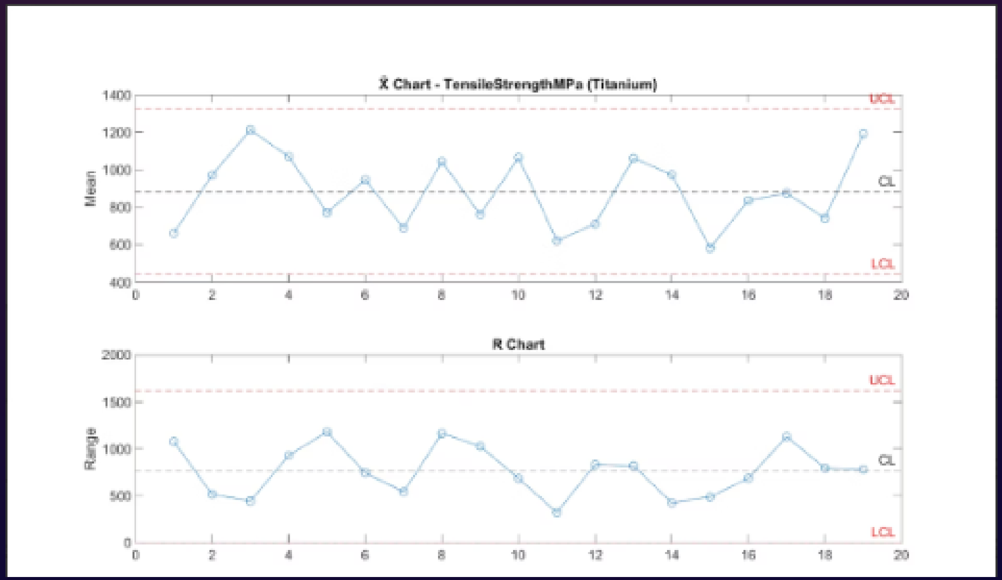
Aluminium



Carbon Fiber

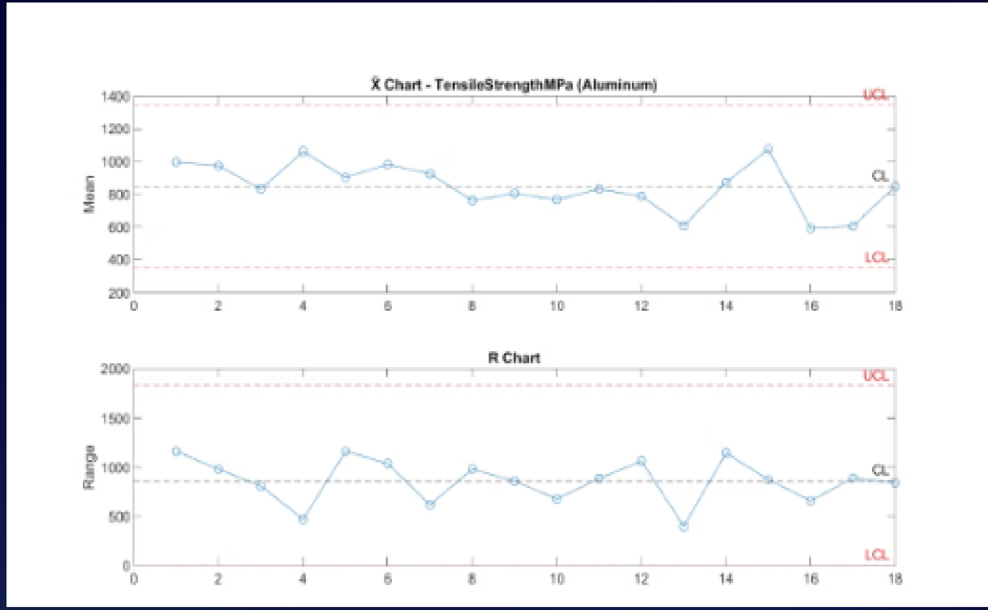


Titanium

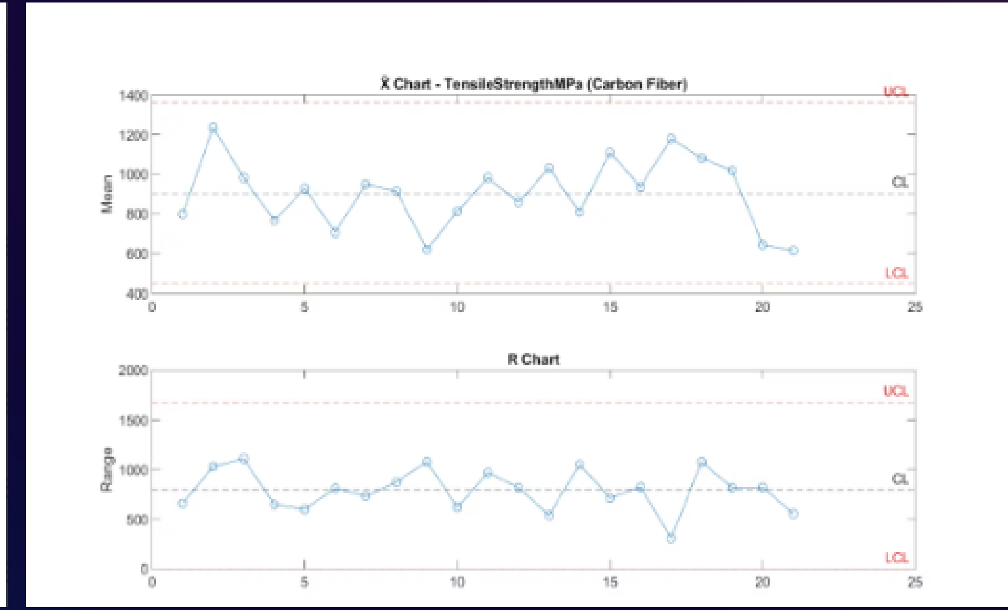


X-R Chart Analysis: Yield Strength

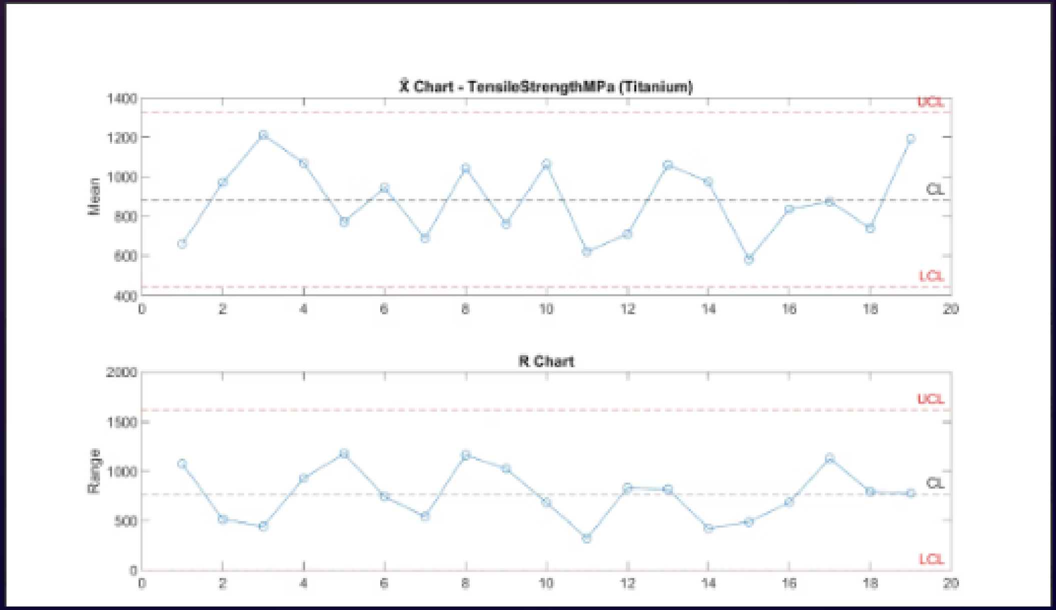
Aluminium



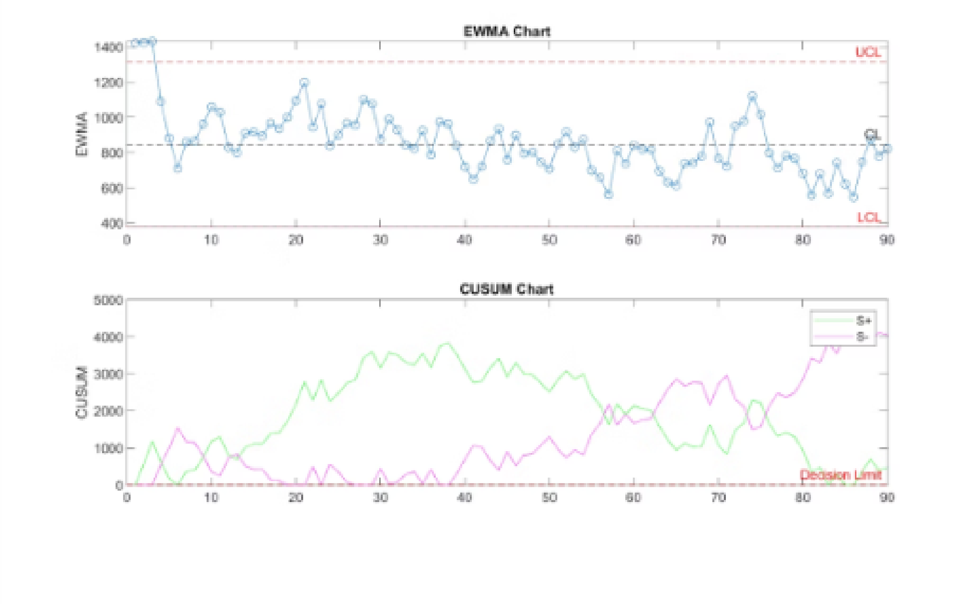
Carbon Fiber



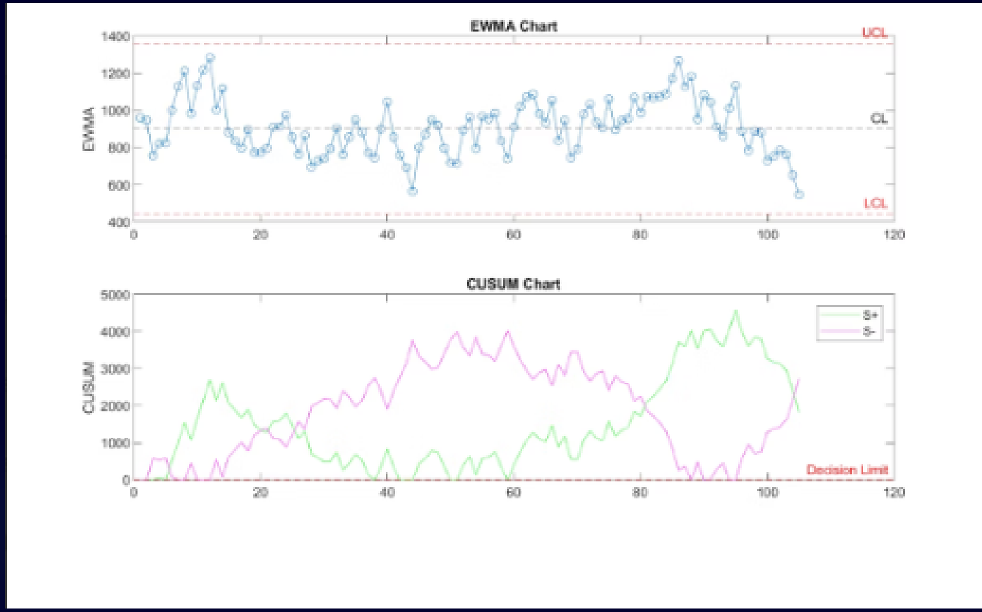
Titanium



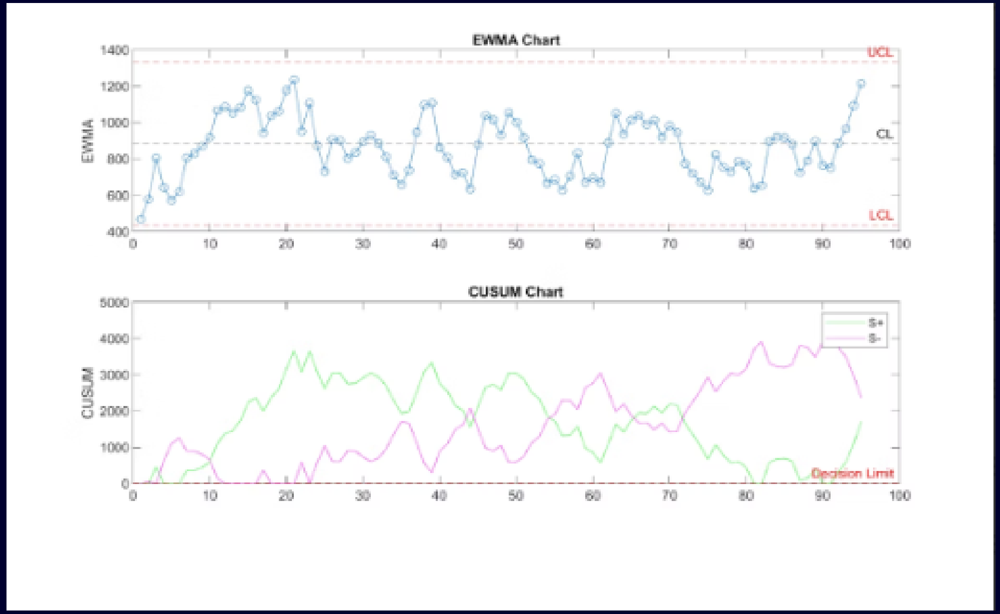
CUSUM and EWMA - Tensile Strength



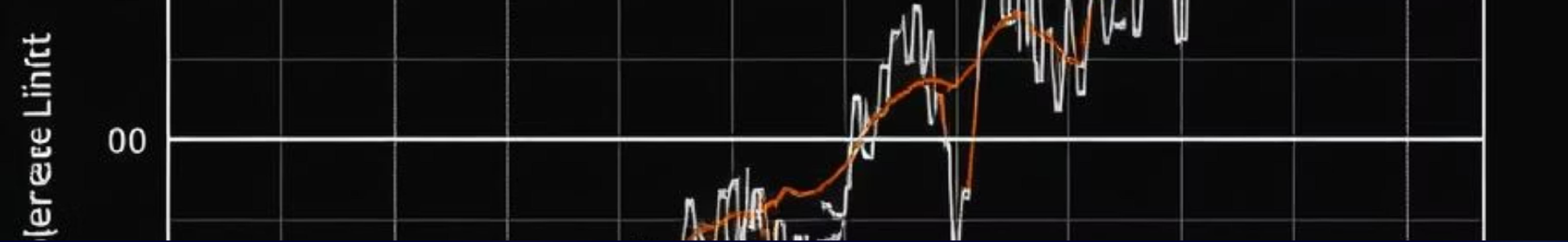
Aluminium



Carbon fibre



Titanium



CUSUM and EWMA Trends: Detecting Process Shifts

CUSUM and EWMA charts are used to detect subtle shifts in the process that may not be apparent in X-R charts. These techniques accumulate deviations from the target value, making it easier to identify small but consistent changes. Analyzing CUSUM and EWMA trends enables proactive intervention to maintain process stability.

Aluminium

- **Initial downward trend** in EWMA stabilizes later.
- CUSUM S+ shows early shift, then levels off.
- **Conclusion**: Early variation, but tensile strength stabilizes – overall **process in control**.

Titanium

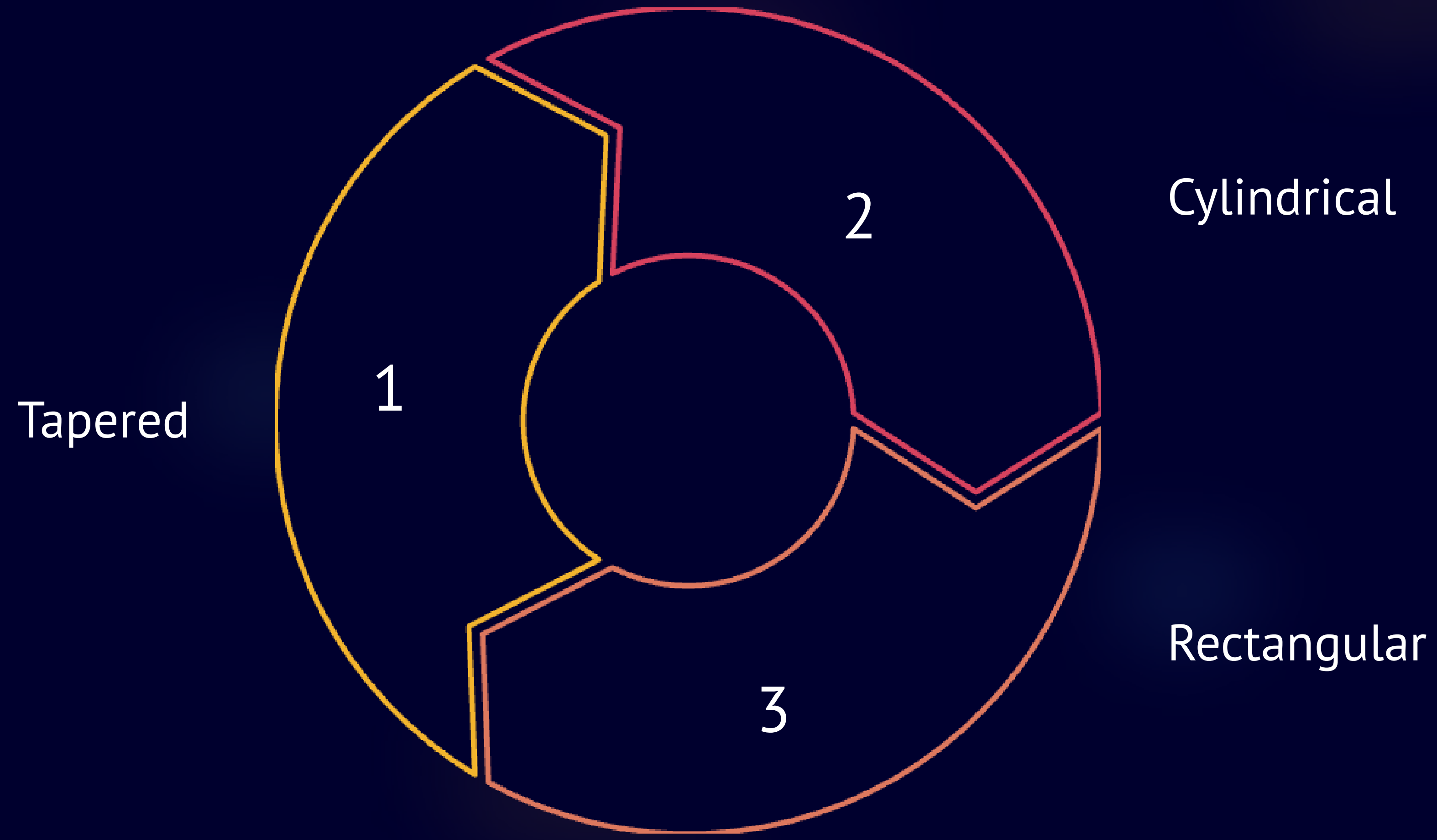
- EWMA remains flat and centered.
- CUSUM S+ and S– fluctuate slightly but stay within limits.
- **Conclusion**: Consistently stable process – **best material for tensile reliability**.

Carbon Fibre

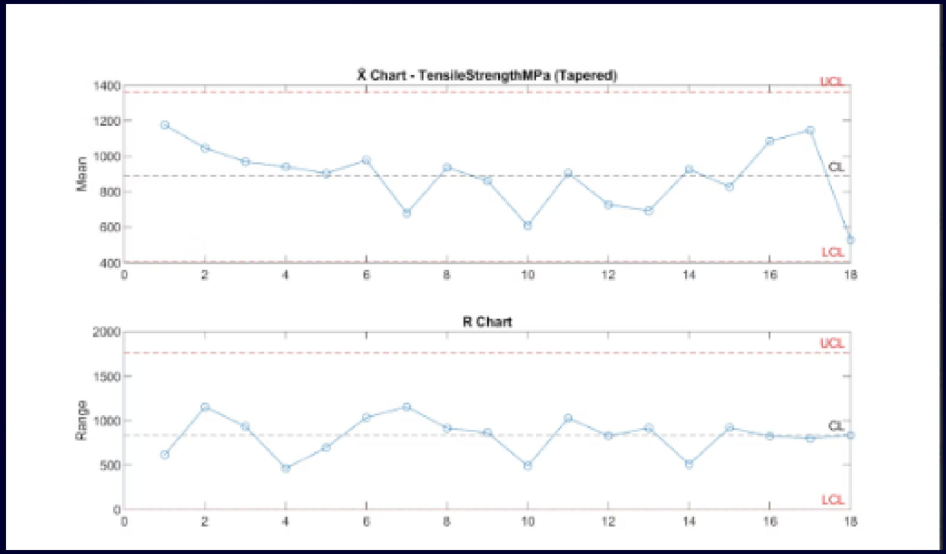
- EWMA shows rising trend near the end.
- CUSUM S+ climbs steadily after sample 60.
- **Conclusion**: **Persistent upward shift** in tensile strength – **requires investigation**.

X-R Chart Analysis by Shape

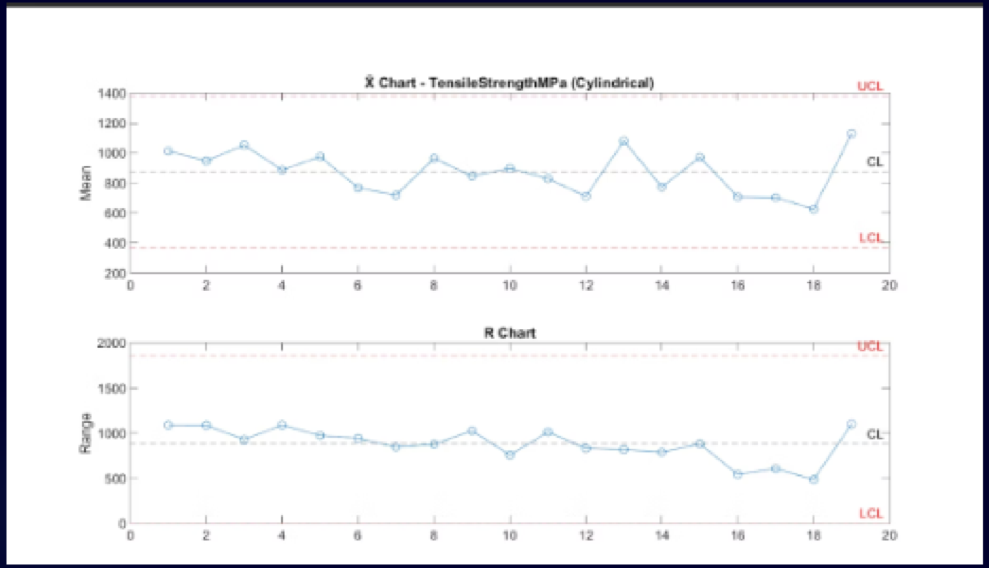
Analyzing X-R charts for each structural shape—tapered, cylindrical, and rectangular—allows for a detailed comparison of process performance. This analysis helps identify whether specific shapes exhibit greater variability or instability compared to others. The goal is to tailor control measures to the unique characteristics of each shape.



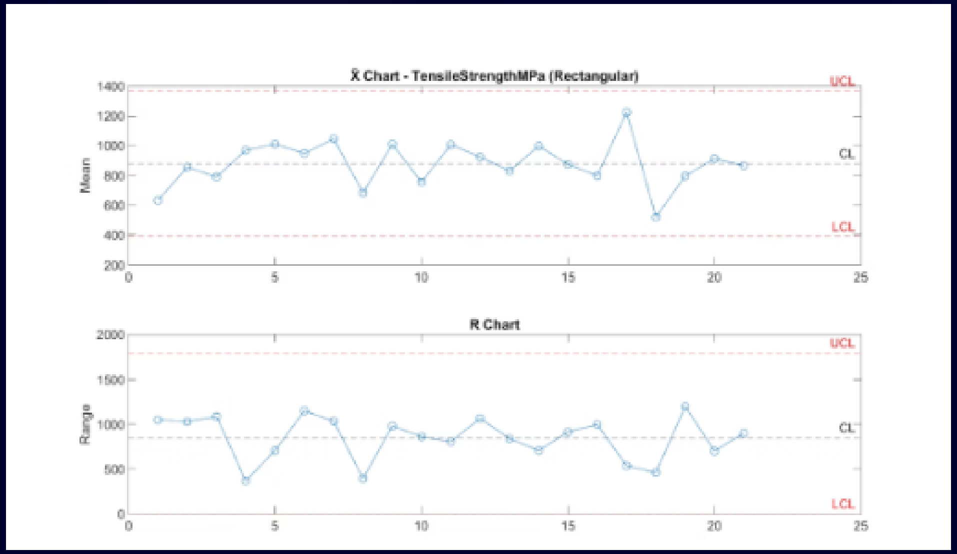
X-R Chart - Tensile Strength



Tapered

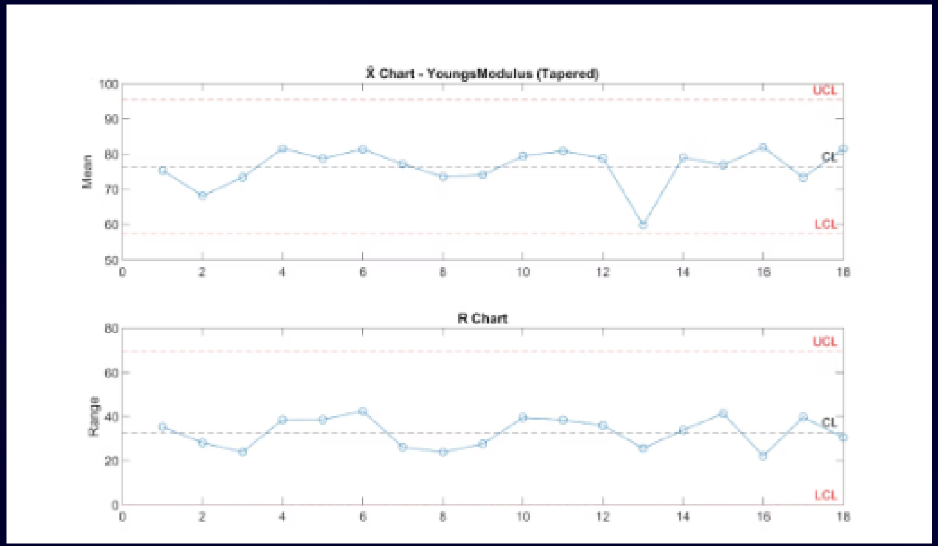


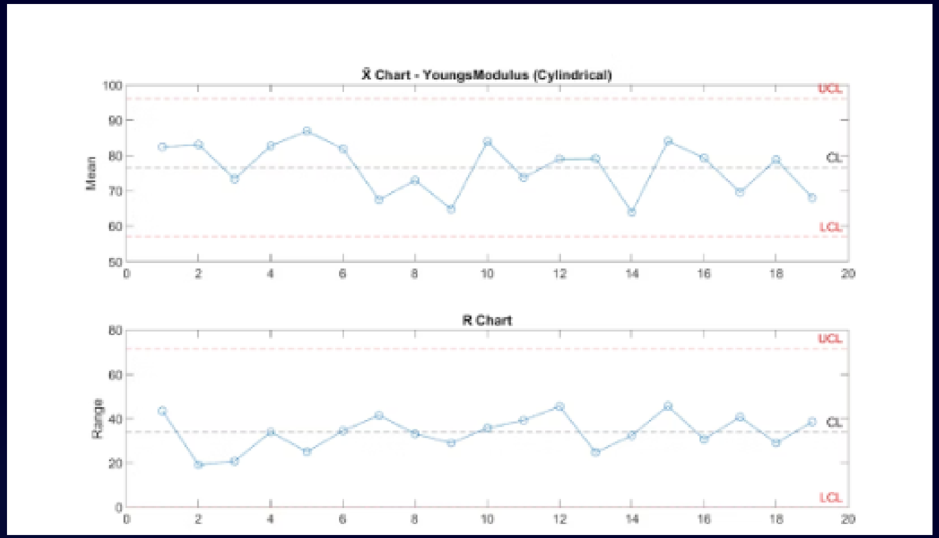
Cylindrical

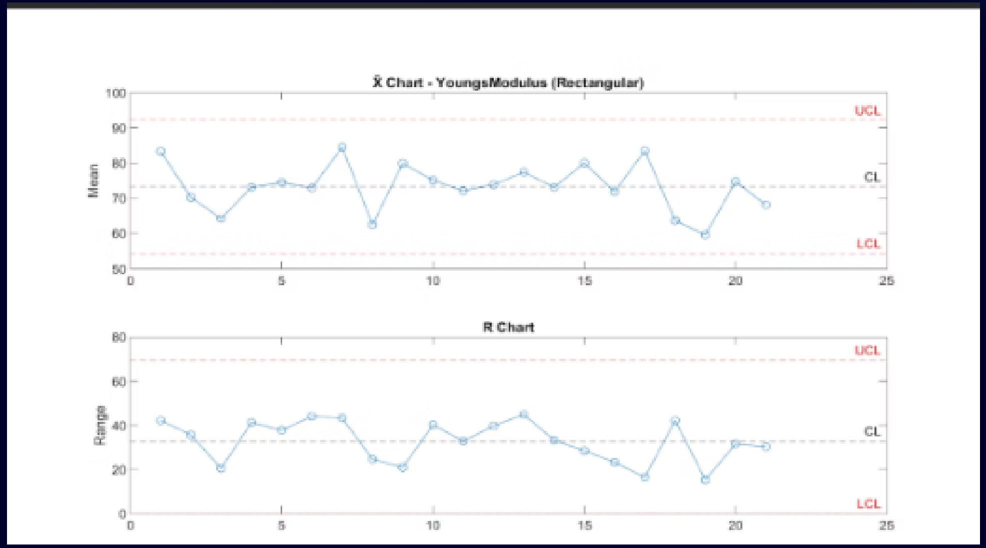


Rectangular

X-R Chart - Young's Modulus (Elasticity)





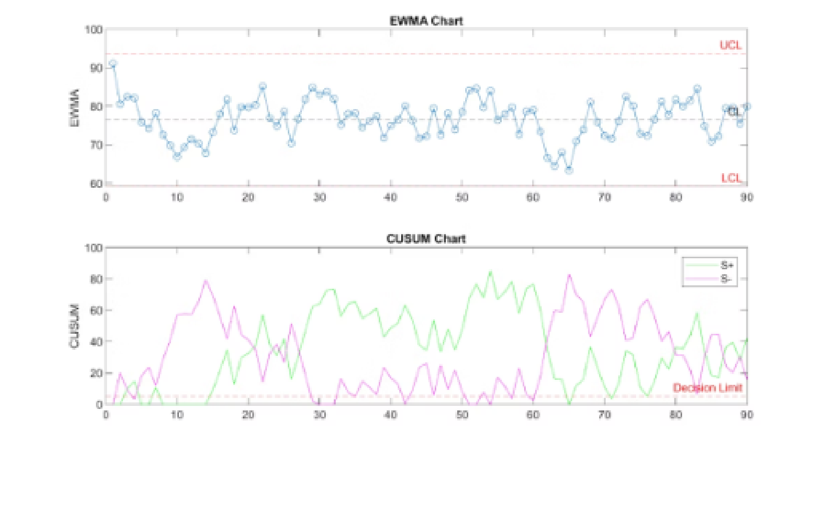


Tapered

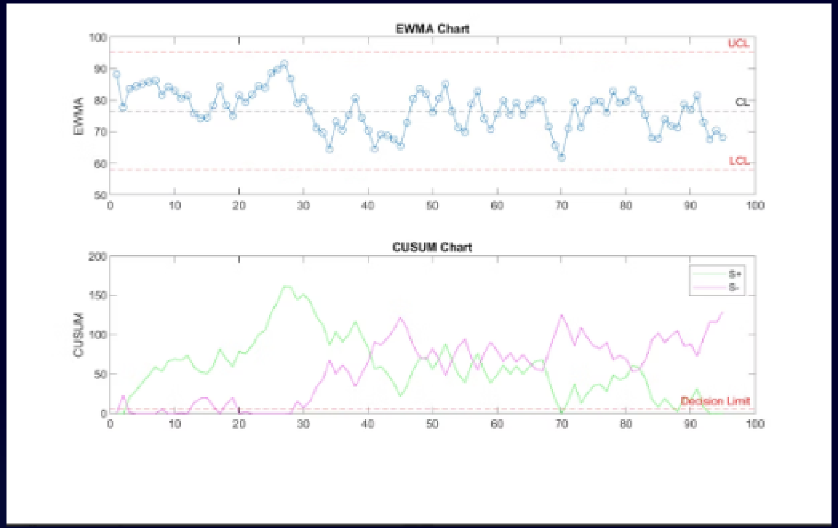
Cylindrical

Rectangular

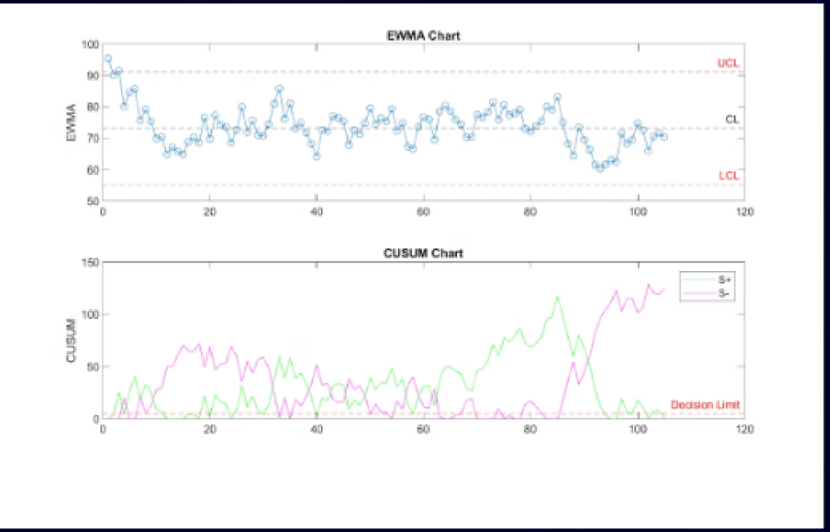
CUSUM and EWMA - Young's Modulus



Tapered



Cylindrical



Rectangular

CUSUM and EWMA Trends

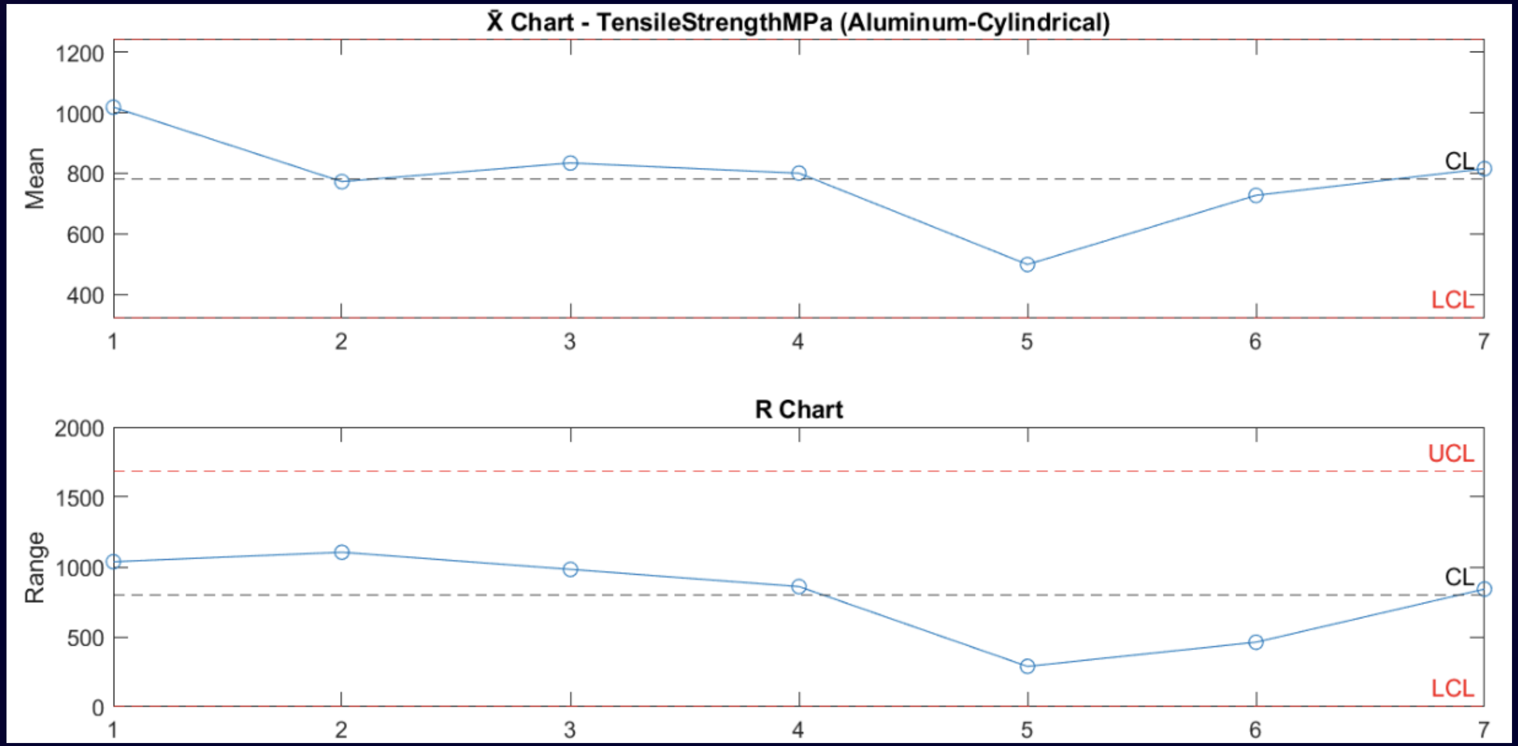
We can identify subtle shifts with CUSUM and EWMA trends. These charts provide insights into the long-term process behavior for tensile strength, thickness, and deflection. By analyzing these trends, we can anticipate and address potential issues before they lead to significant deviations from desired specifications.

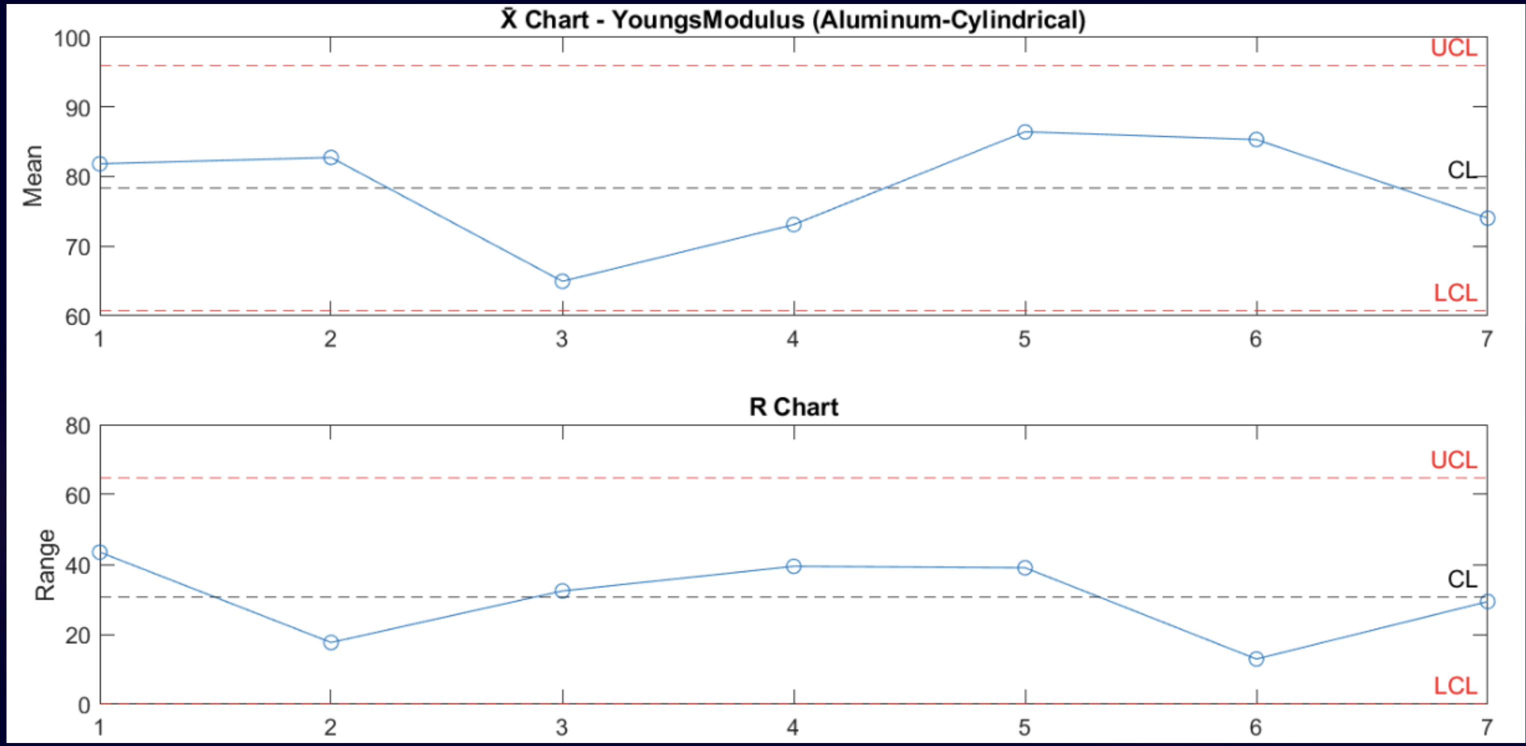
1. Trend Analysis: **Tapered** parts show **good stability** and are well under control.

2. Shift Detection: **Cylindrical** parts indicate **emerging shifts**, requiring **close observation and preventive measures**.

3. Proactive Action: **Rectangular** parts show **clear process shift**, demanding **urgent intervention** to avoid further deviation in material behavior.

Integrating Material Type and Shape -Aluminum+Cylinder **X-R :**



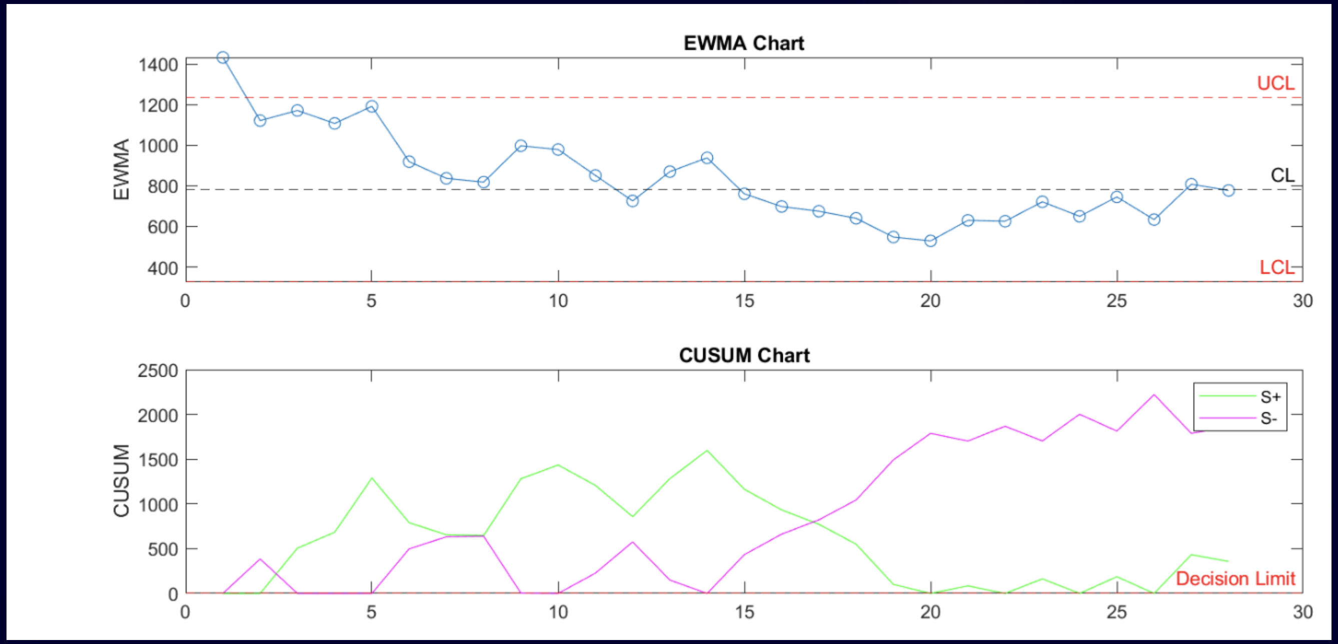


Tensile Strength

Youngs Modulus

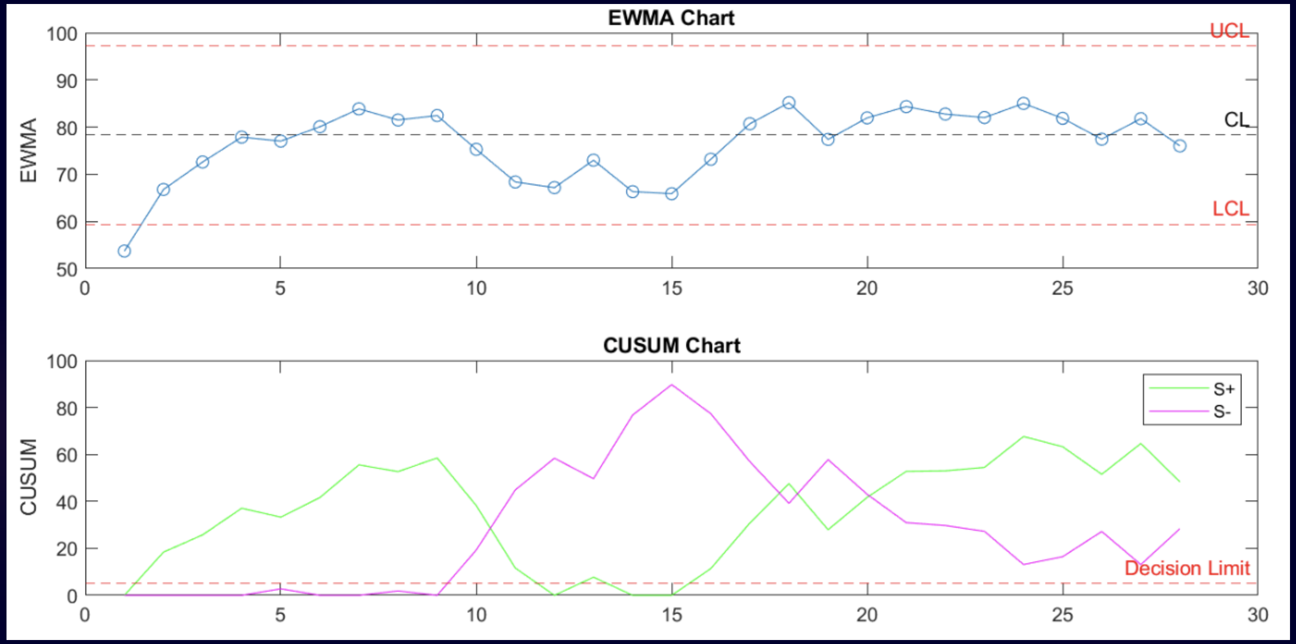
Integrating Material Type and Shape –Aluminum + Cylinder

CUSUM,EWMA



Tensile Strength

- Process is **out-of-control**; **tensile strength is deteriorating** and requires **immediate corrective action**

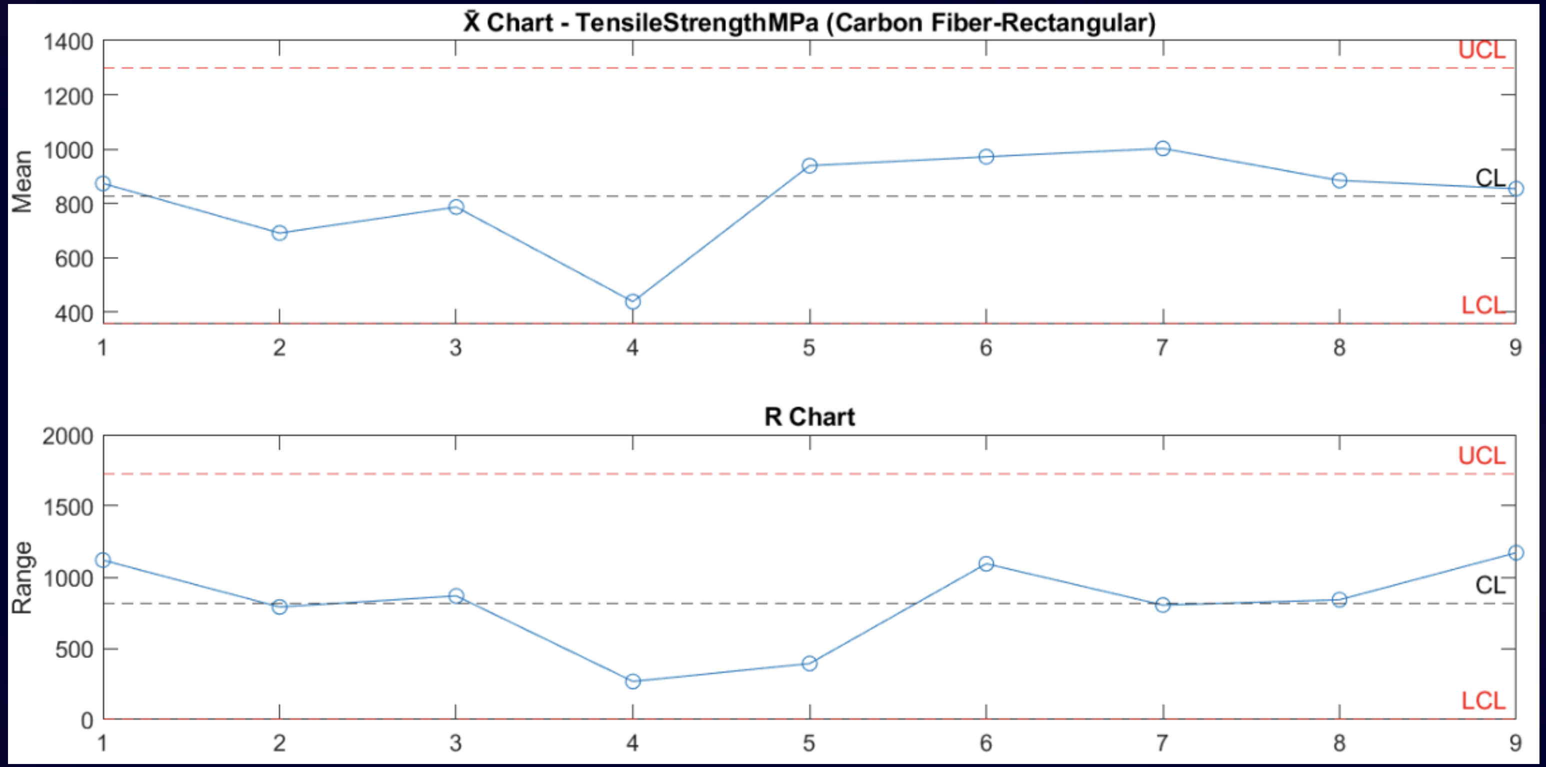


Youngs Modulus

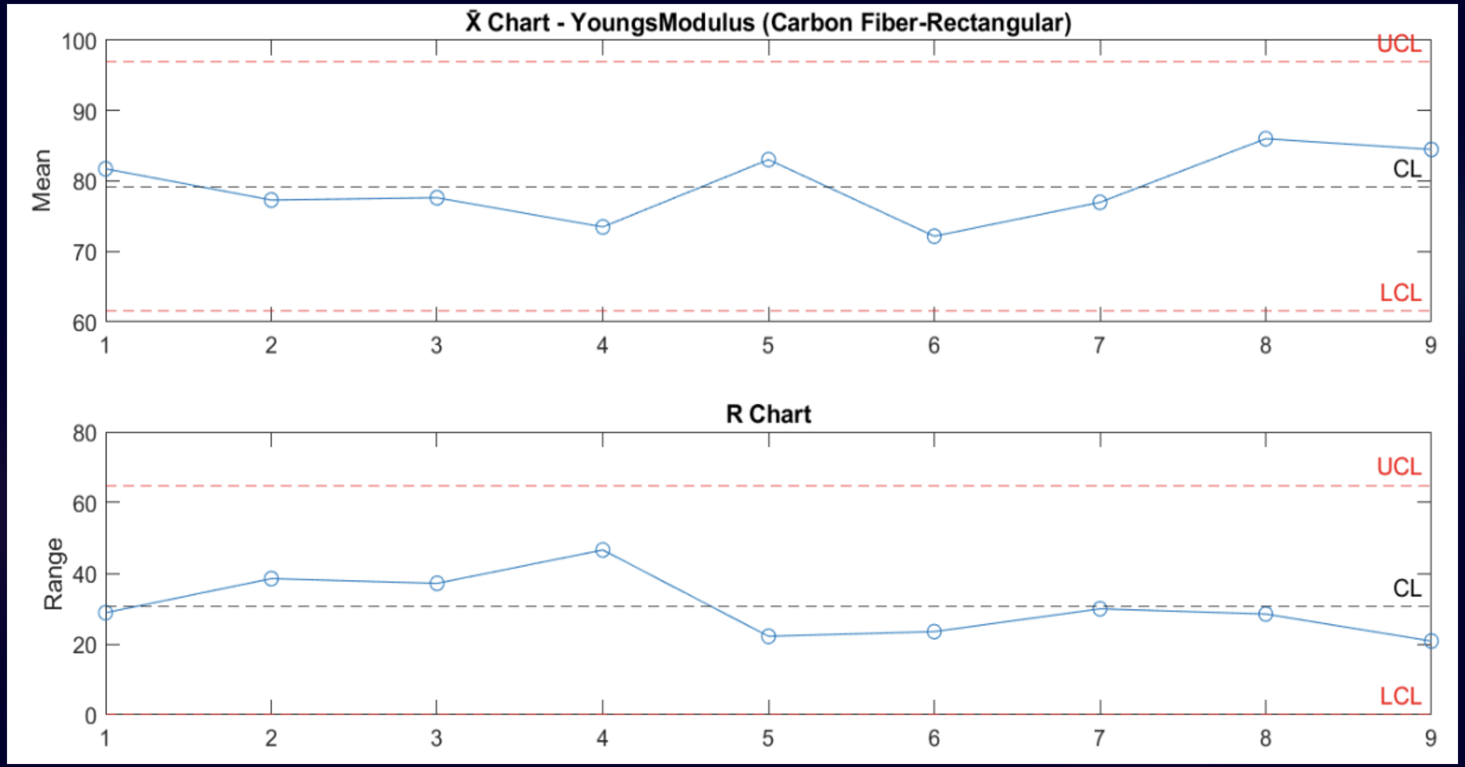
- **Process is in control and stable.**

No significant shift detected — **no corrective action needed**, just continue regular monitoring.

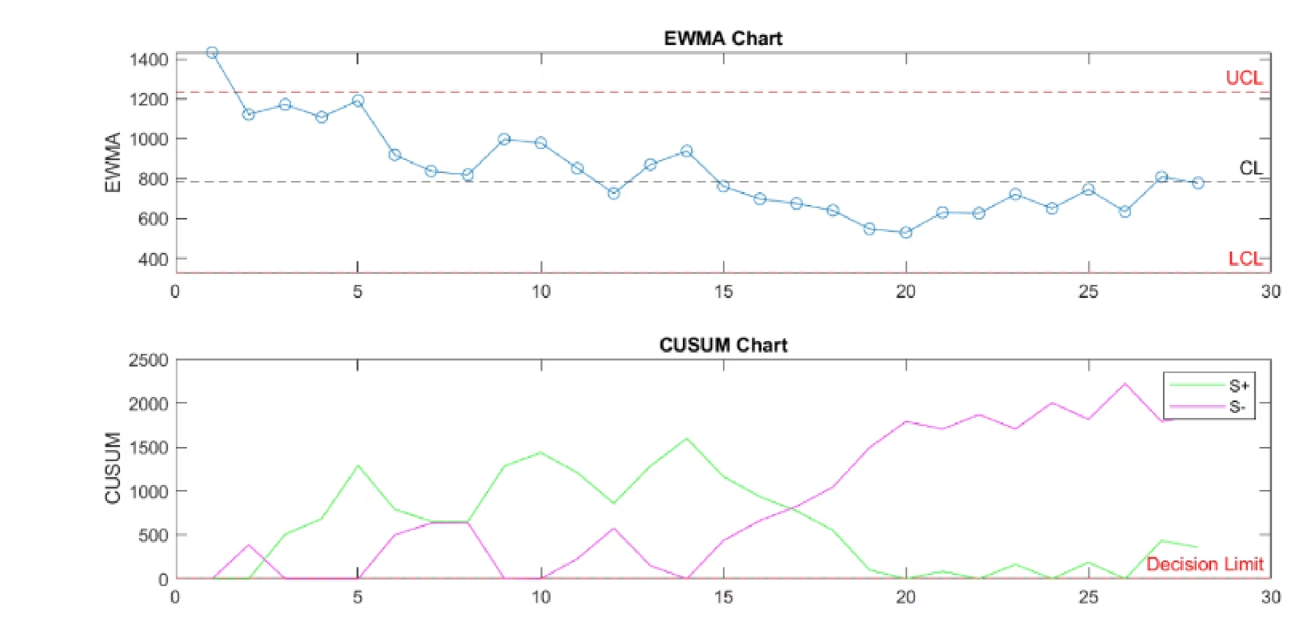
Integrating Material Type and Shape - Carbon fibre+ Rectangle **X-R :**



Tensile Strength

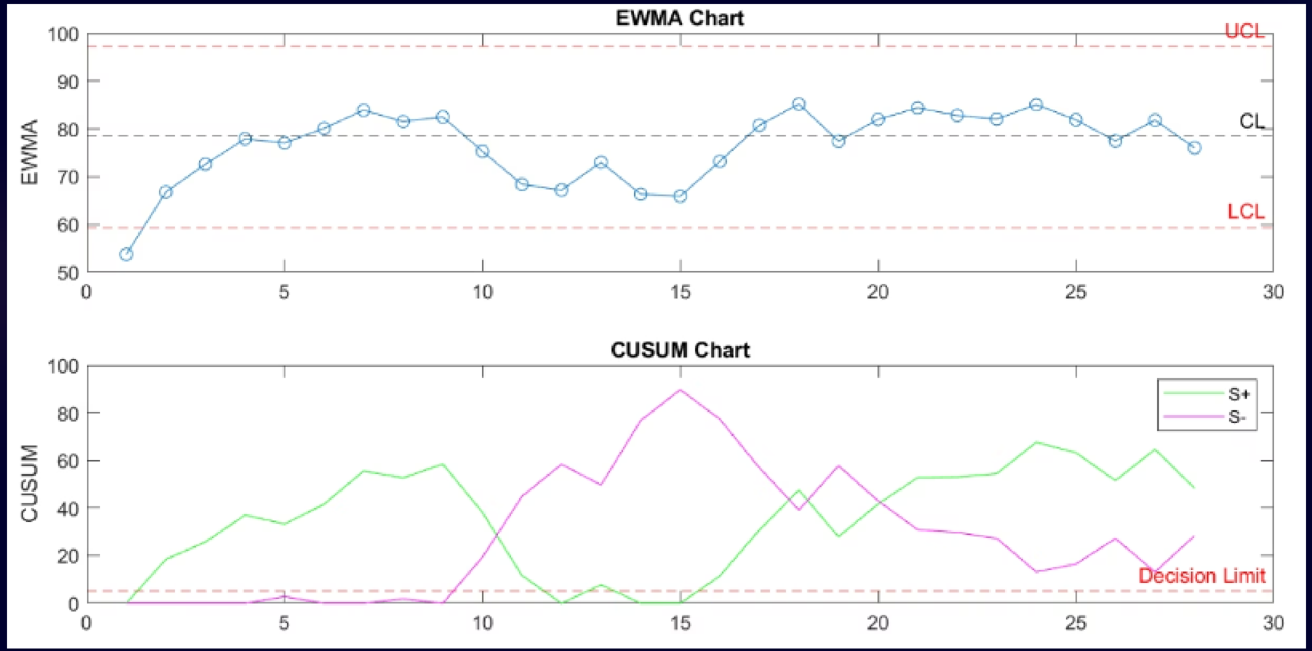


Youngs Modulus



Tensile Strength

- Process is **out-of-control**; **tensile strength is deteriorating** and requires **immediate corrective action**.

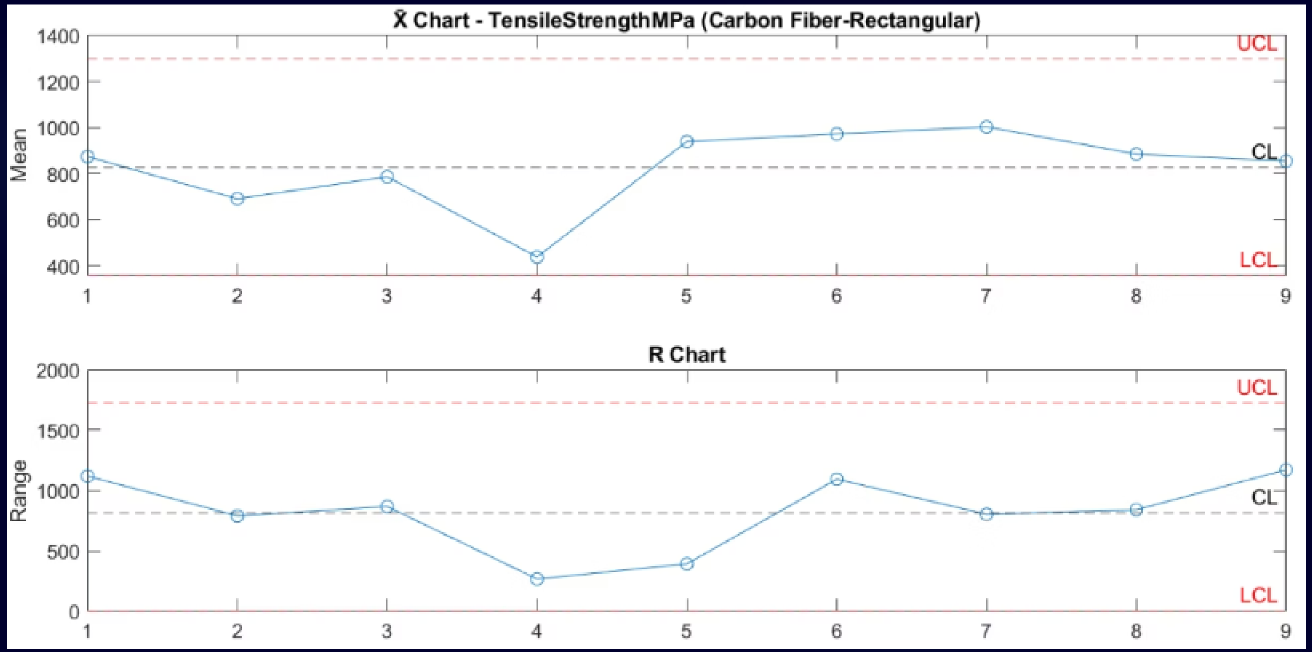


Youngs Modulus

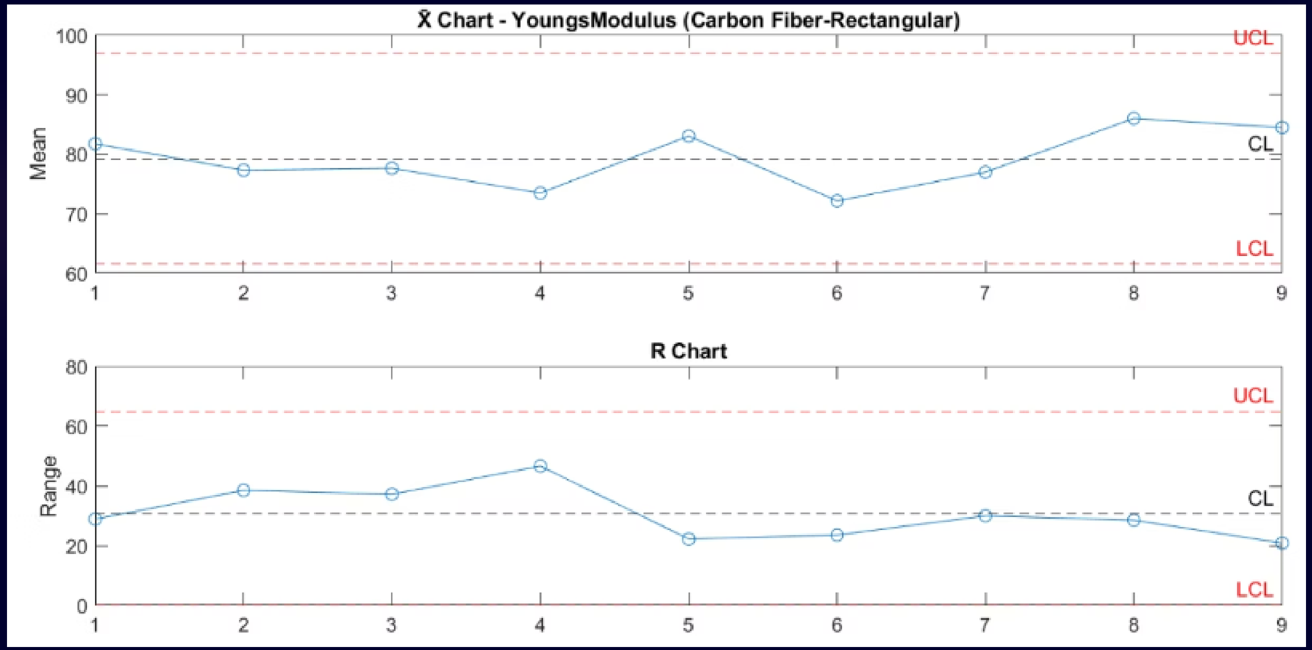
- **Process is in control and stable.**
- No significant shift detected – **no corrective action needed**, just continue regular monitoring.

Integrating Material Type and Shape - Carbon fibre+ Rectangle

X-R :



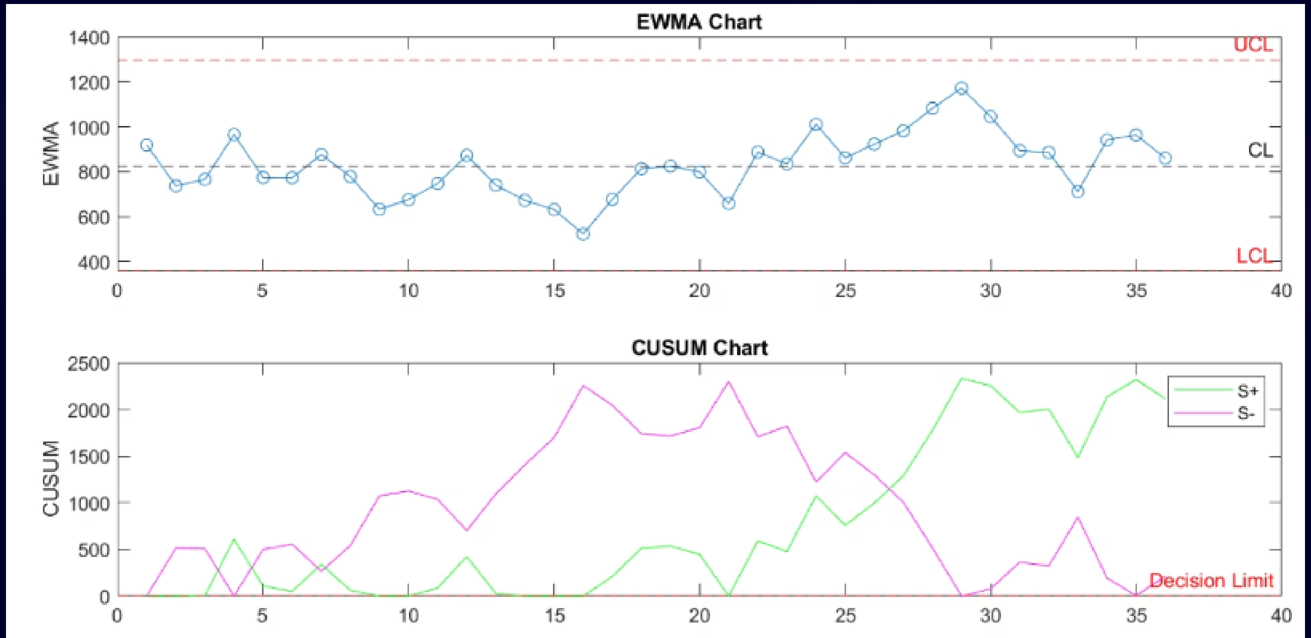
Tensile Strength



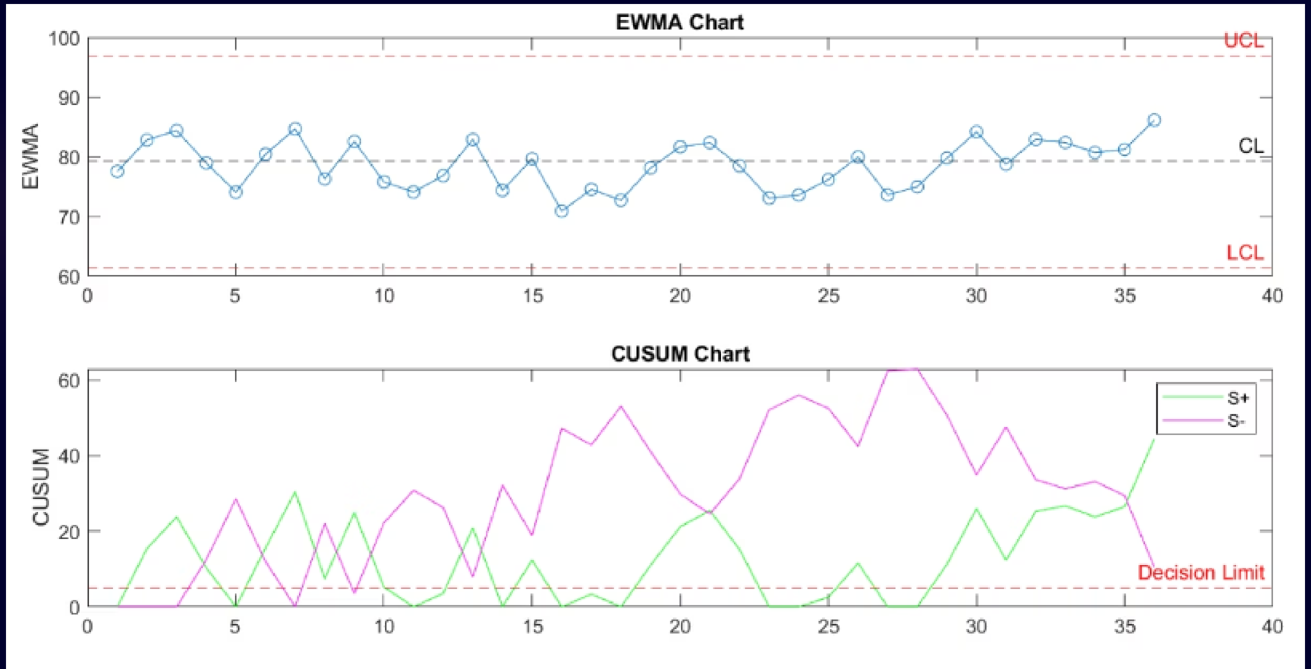
Youngs Modulus

Integrating Material Type and Shape -Carbon fibre and Rectangle

CUSUM,EWMA :



Tensile Strength



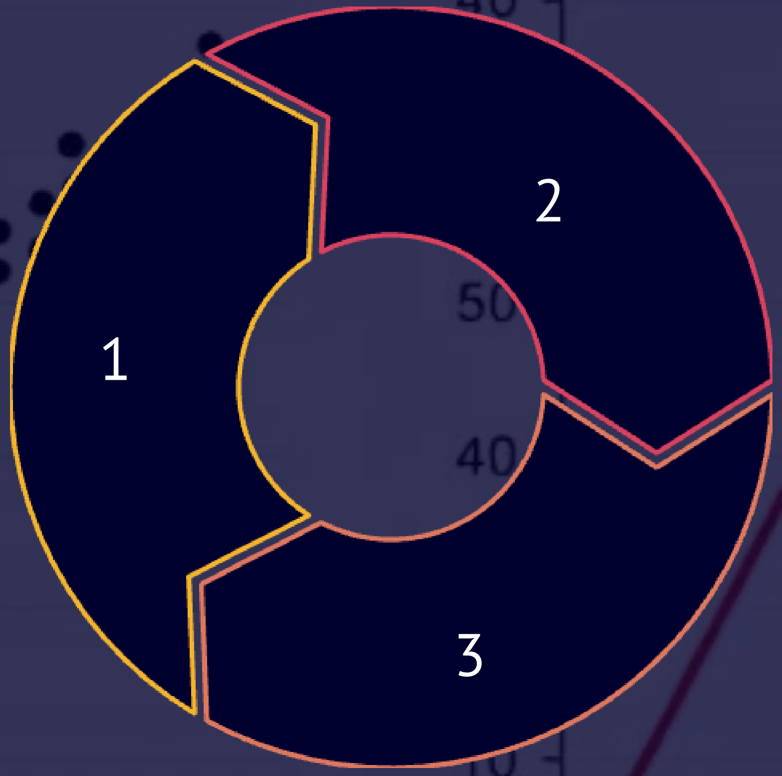
Youngs Modulus

CUSUM and EWMA Trends

We can identify subtle shifts with CUSUM and EWMA trends. These charts provide insights into the long-term process behavior for tensile strength, thickness, and deflection. By analyzing these trends, we can anticipate and address potential issues before they lead to significant deviations from desired specifications.

Trend Analysis:

Aluminum+Cylinder shows a declining trend in tensile strength and stable variation in Young’s Modulus, while Carbon Fiber+Rectangle shows a recovery trend in tensile strength and consistently stable behavior in Young’s Modulus.



Shift Detection: Aluminum+Cylinder shows a clear shift in tensile strength (CUSUM crossing limits) but no shift in Young’s Modulus, while Carbon Fiber+Rectangle shows shift patterns in both tensile strength and Young’s Modulus, though less severe in the latter.

Proactive Action: Aluminum+Cylinder requires immediate corrective action for tensile strength and routine monitoring for Young’s Modulus, while Carbon Fiber+Rectangle needs investigation and adjustment for tensile strength and continued observation for Young’s Modulus..

Future Work

For future work, we can explore integrating multiple design choices based on critical aspects. For example, we could analyze the performance of carbon fiber materials with a tapered shape, examining metrics like optimization time and parts per defect.

1

Integrate Design Choices

Explore combining different materials, shapes, and other parameters to optimize for key performance indicators.

2

Analyze Carbon Fiber with Tapered Shape

Evaluate how carbon fiber with a tapered design impacts optimization time and defect rates.

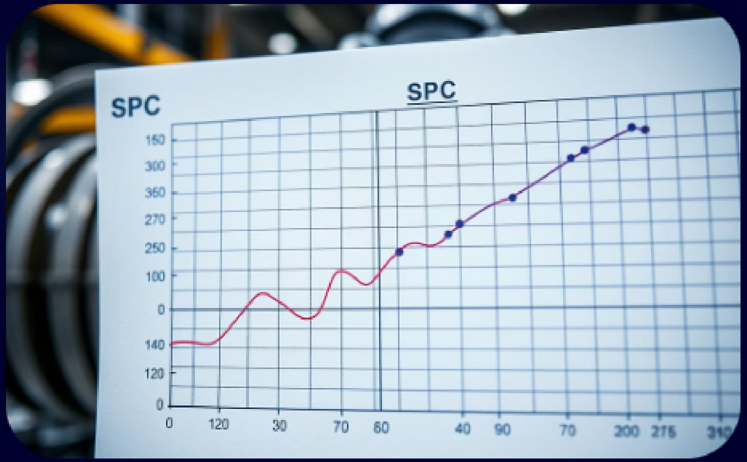
3

Expand to Other Metrics

Consider additional critical aspects beyond just optimization and defects, such as weight, strength, and cost.

Conclusion:

Statistical Process Control (SPC) is critical for maintaining high quality in aerospace manufacturing. By using SPC, manufacturers can effectively monitor and control key parameters that affect component integrity and performance.



SPC in Aerospace

SPC enables early detection of process variations, preventing defects and minimizing rework through the use of control charts.

Prototyping and Early Detection

Implementing SPC during prototyping allows for early process optimization. CUSUM and EWMA charts are particularly useful for identifying subtle shifts.

Integrating Material and Shape

Analyzing how material and shape interact helps to refine processes and identify optimal design combinations.

Strategic implementation of SPC ensures consistent component integrity, starting from the prototyping phase. This promotes innovation, reduces waste, and contributes to the production of safer aircraft.

Thank You

We appreciate your attention and engagement. Now, we'd love to hear your questions.

Open to Q&A