Practical Tools for Measurement Systems Analysis

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Practical Tools for Measurement Systems Analysis

Presentation Outline

- Conventional Gage R&R Metrics – basic familiarity assumed
- Thought process for Measurement Systems Analysis
- Practical approaches and tools
- Examples

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- Measurement Systems Analysis – Gage R&R
  - Assesses Repeatability and Reproducibility

- Metric-based way of drawing conclusions from Gage R&R Studies: percentages per AIAG MSA Handbook
  - %Study Variation: compares measurement system variation to overall variation (measurement system and part-to-part)
  - %Tolerance: compares measurement system variation to tolerance
  - Guidelines: 10/30% rule

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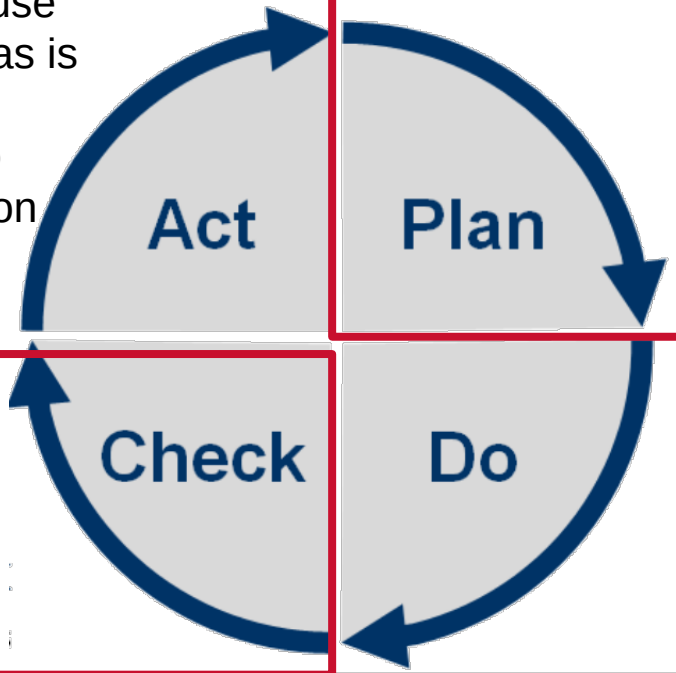
Measurement Systems Analysis Process

Decision

1. Results satisfactory – use measurement system as is
2. Collect more data
3. Make improvements to current system based on findings



- Define scope
- Measurement application
- Sample selection strategy
- Strategy for appraisers
- Define execution plan
- Data collection plan
- Assessment criteria

- Execute study based on plan

- Study results
- Assess if results are in line with expectations

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- **“PGA” Approach**
  - Practical
  - Graphical
  - Analytical

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Practical

- Going into the study: what is the purpose of the measurement?
  - How big of a difference am I trying to detect? “Signal to Noise”
  - What are my specification limits? Where is my process running?
- Is there anything about the raw data that visually stands out?

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Graphical

- Graphical look
- Is there anything about the data that graphically stands out?
- Chart study results and look for clues – shifts, drifts, patterns, special causes etc.

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Analytical

- This should be the last step of your analysis
- Be careful about what you choose to be the metric of the analysis

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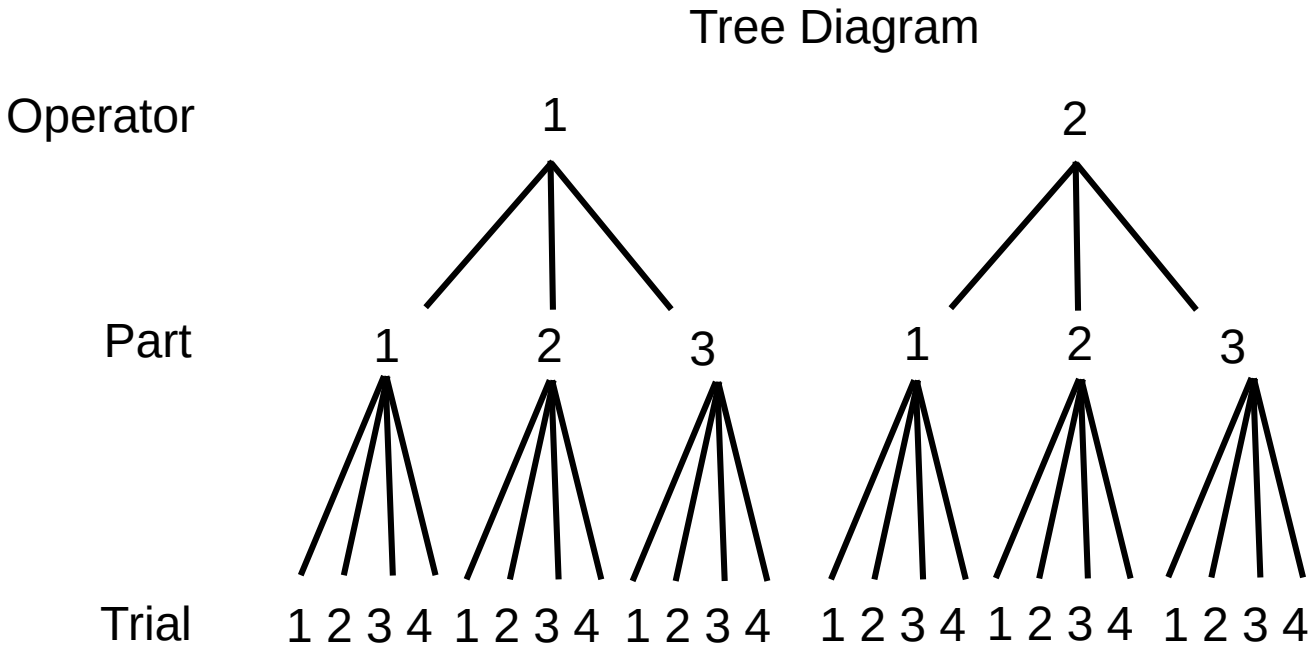
Example of PGA Approach: Gage R&R for optical wall thickness measurement

- Optical measurement
- Extruded components
- Specification: .012”-.013”



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Practical

Visual – Raw data

Specification: .012”-.013”

Sample	Operator	Trial	WT
1	1	1	0.01205
2	1	1	0.01247
3	1	1	0.01200
1	1	2	0.01206
2	1	2	0.01248
3	1	2	0.01196
1	1	3	0.01206
2	1	3	0.01247
3	1	3	0.01197
1	1	4	0.01206
2	1	4	0.01247
3	1	4	0.01203
1	2	1	0.01203
2	2	1	0.01250
3	2	1	0.01195
1	2	2	0.01199
2	2	2	0.01251
3	2	2	0.01188
1	2	3	0.01197
2	2	3	0.01250
3	2	3	0.01198
1	2	4	0.01201
2	2	4	0.01242
3	2	4	0.01189

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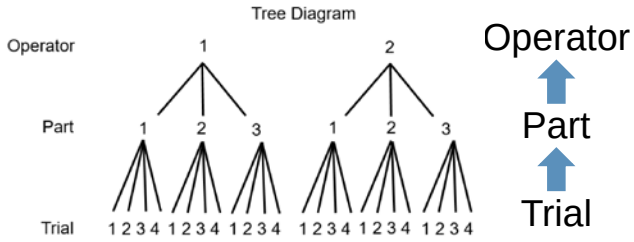
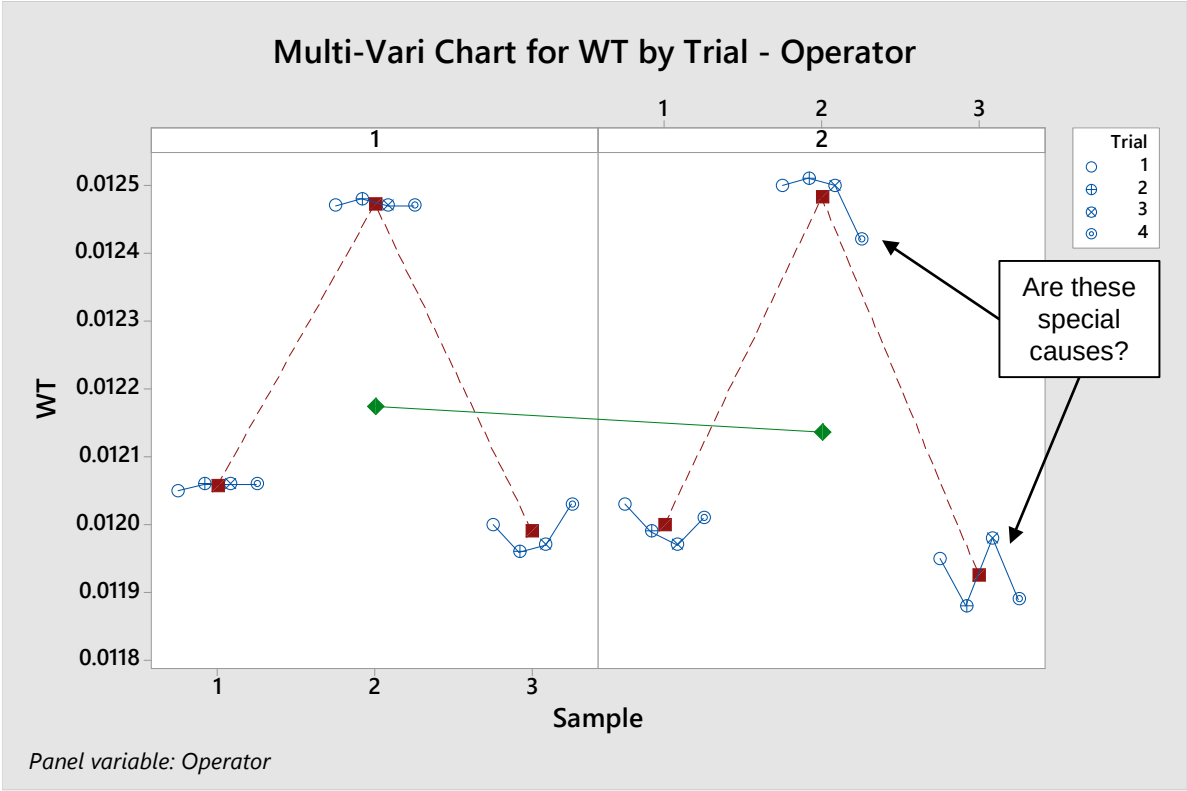
Graphical

Tool: Multi-Vari Chart

- Ability to compare variation across factors
- Bottom-up



- Ability to look for patterns in the data



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Graphical & Analytical I.

Tool: Xbar-R behavior chart

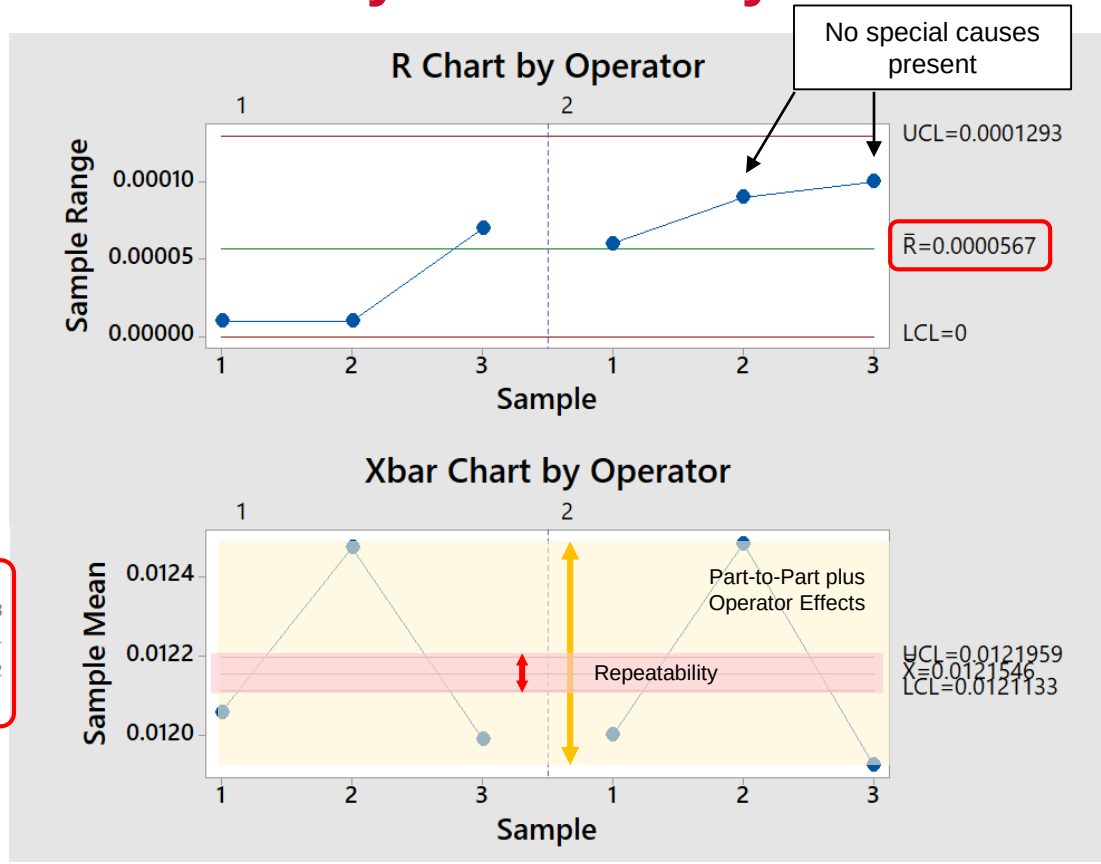
- Charts staged by operator

$$UCL_R = D_4 * \bar{R} \qquad UCL_x = \bar{\bar{X}} + A_2 * \bar{R}$$

$$LCL_R = D_3 * \bar{R} \qquad LCL_x = \bar{\bar{X}} - A_2 * \bar{R}$$

Tabular values for X-bar and range charts

Subgroup Size	A_2	d_2	D_3	D_4
2	1.880	1.128	-----	3.268
3	1.023	1.693	-----	2.574
4	0.729	2.059	-----	2.282
5	0.577	2.326	-----	2.114



- Xbar chart shows repeatability vs. part-to-part variation

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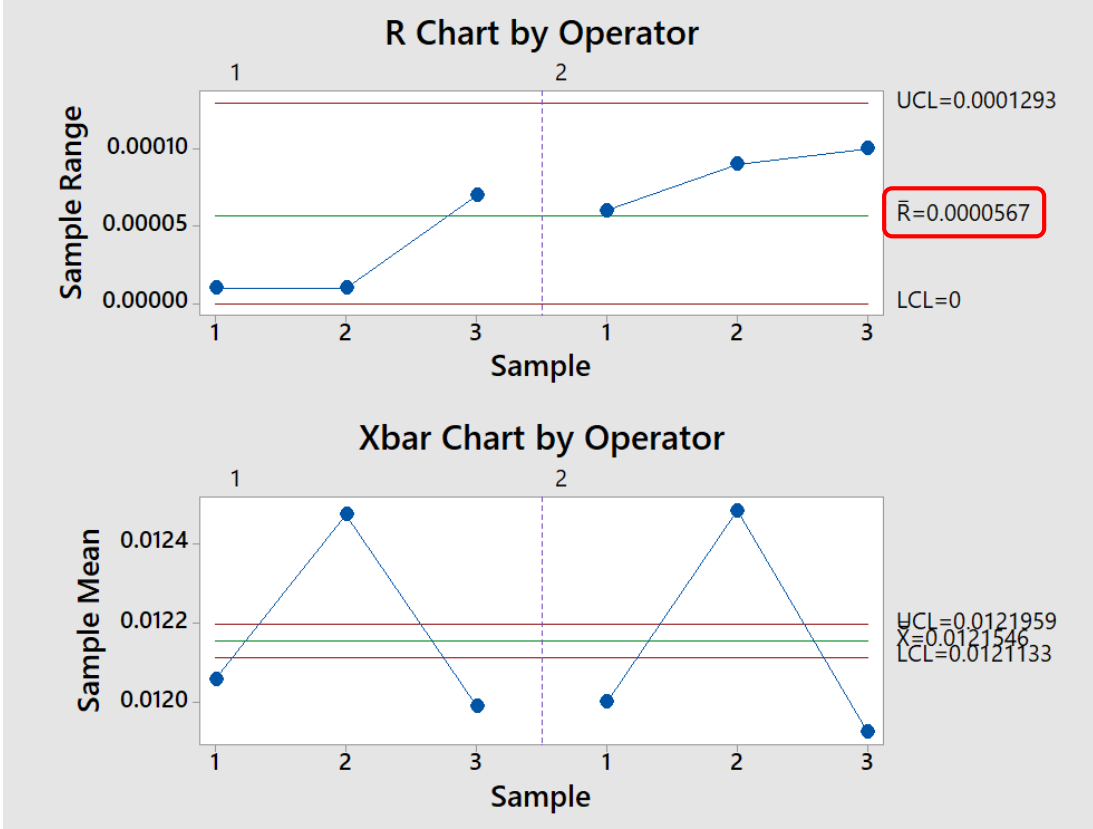
Graphical & Analytical II.

Tool: Xbar-R behavior chart

- Rbar: represents average repeatability error
- Ranges above control limit on R chart need to be investigated

Graphical – Multi-Vari Chart



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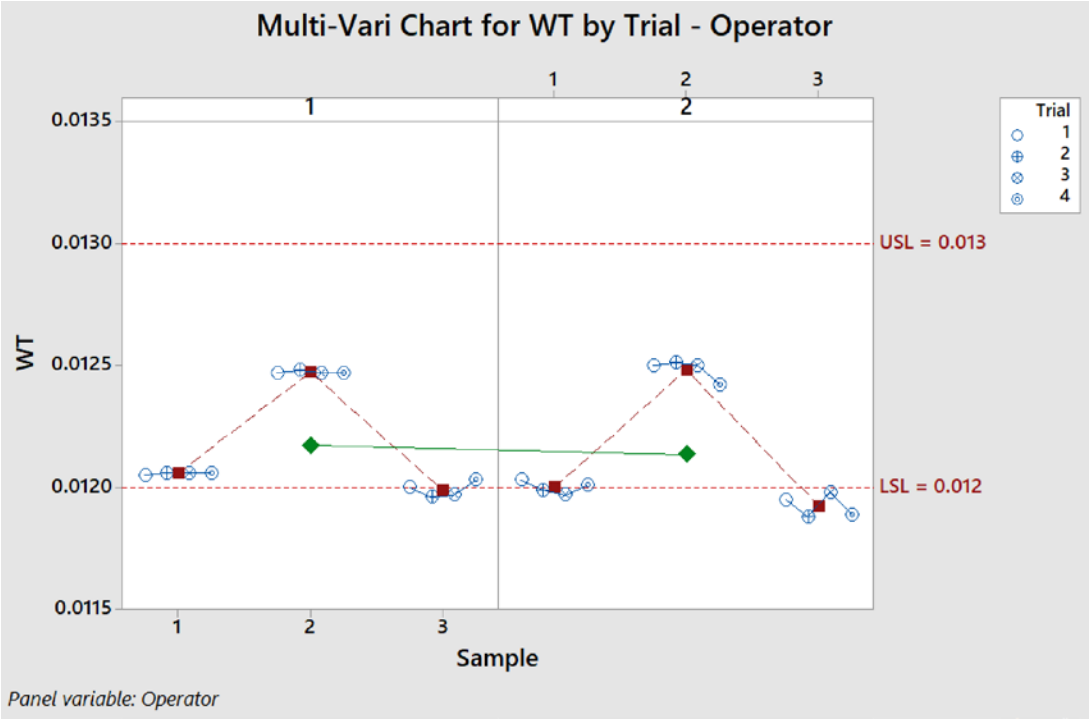
Making a Decision

Scenario #1

Process running close to LSL causing yield issues. Engineer identifies critical process parameters and decides to run a DOE to bring process to nominal

- How big of a difference do you want to be able to detect?
- Rbar = 0.0000567”
- Is the measurement system acceptable for this scenario?



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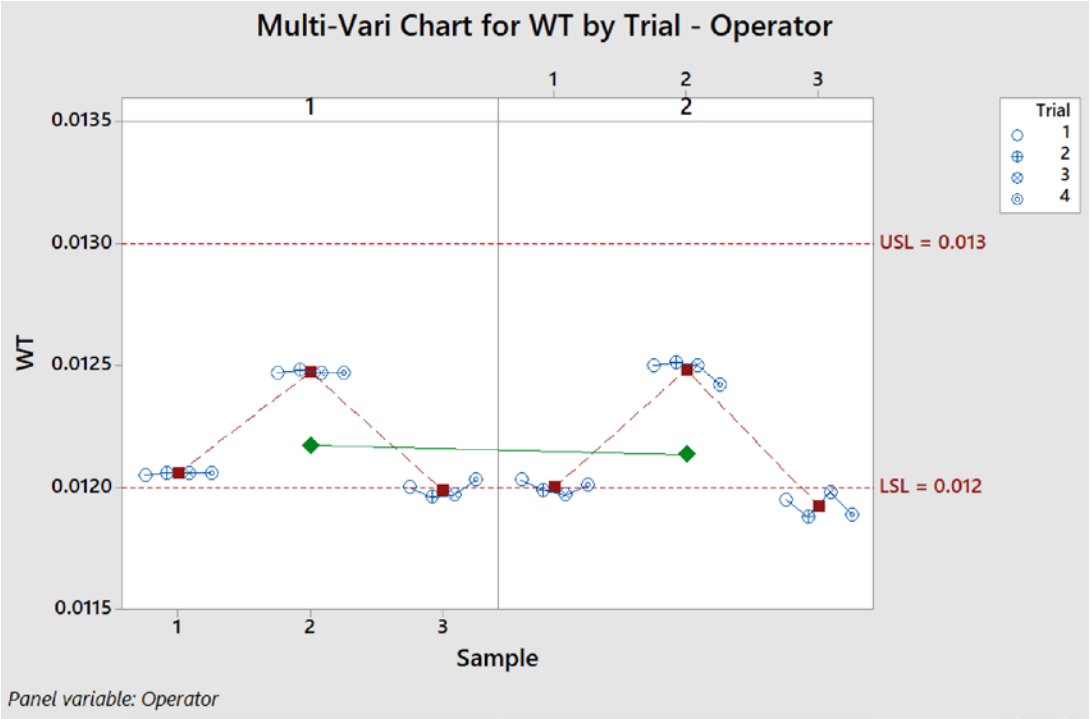
Making a Decision

Scenario #2

Process running close to LSL causing yield issues. Engineer decides to perform 100% sorting

- What is the purpose of the inspection?
- Rbar = 0.0000567”
- %Tolerance = 25.53%Tol.
  - Repeatability = 20.85%Tol.
  - Reproducibility = 14.73%Tol.
- Is the measurement system acceptable for this scenario?
- What is the risk the engineer is running?



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Risk-Based Approach

- Risk of product misclassification
  - Good → Bad
  - Bad → Good
- The closer you are to the specification limits, the higher the risk of misclassification
- How does one quantify the risk of misclassification?

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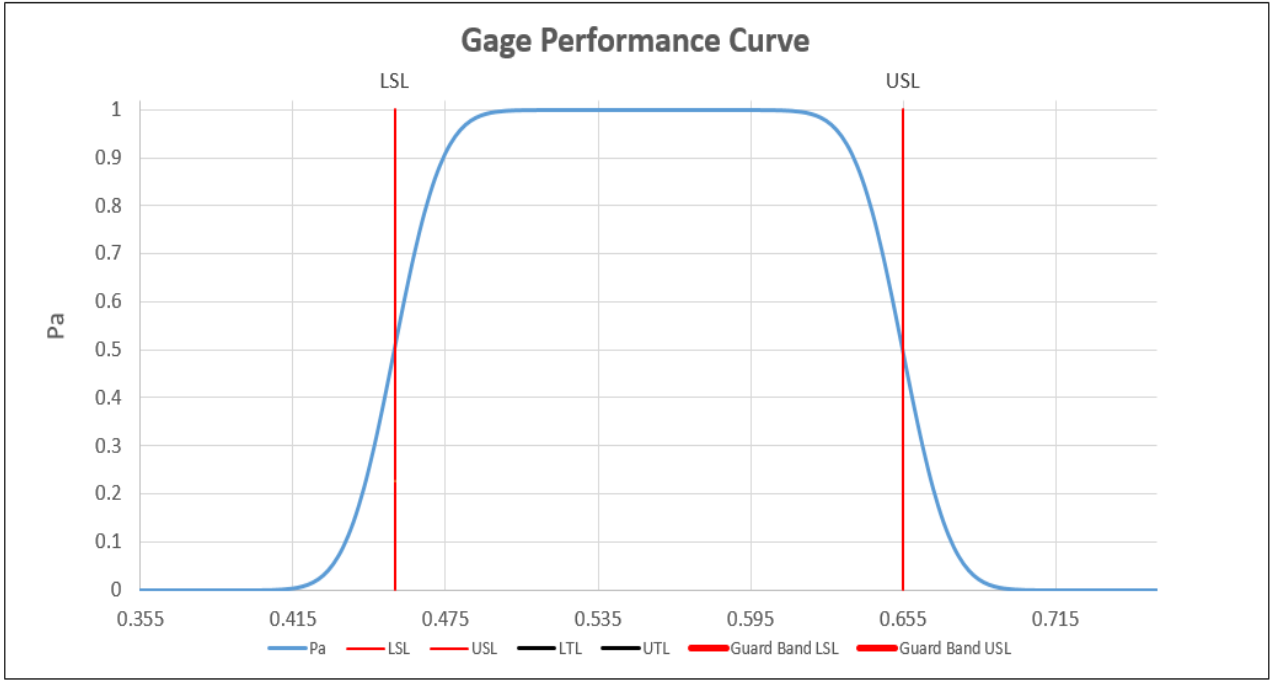
Gage Performance Curve

- Visualizes and quantifies risk of misclassification
- Plotted for individual reference values covering the entire tolerance range and outside of it
- Uses Gage R&R results (StDev) and Z score-based probability calculations to quantify risk



Formula: $P_a = \phi\left(\frac{UL - (X_T + b)}{\sigma}\right) - \phi\left(\frac{LL - (X_T + b)}{\sigma}\right)$

Source: AIAG MSA Reference Manual, 4th Edition

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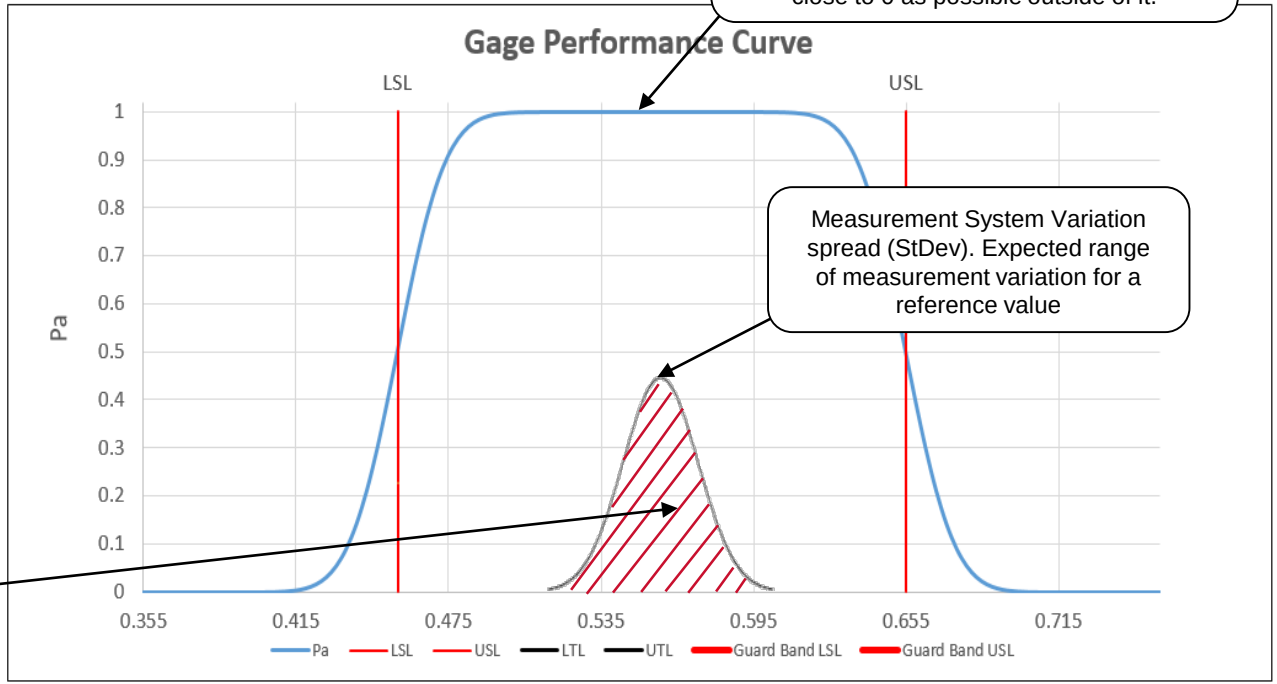
Gage Performance Curve

Measurement System Variation	
LSL	0.455
USL	0.655
Sigma Interval	5.62
StdevGRR	0.015
Variance	0.000225
%Tolerance	**42.15%**

Probability of acceptance (Pa) curve. Ideally, Pa should be as close to 1 as possible inside the specification, and as close to 0 as possible outside of it.



Measurement System Variation spread (StDev). Expected range of measurement variation for a reference value

Probability of acceptance (Pa) – probability of measurements falling inside spec limits – calc. using Z scores*

Measurement System Variation (GR&R)

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Gage Performance Curve

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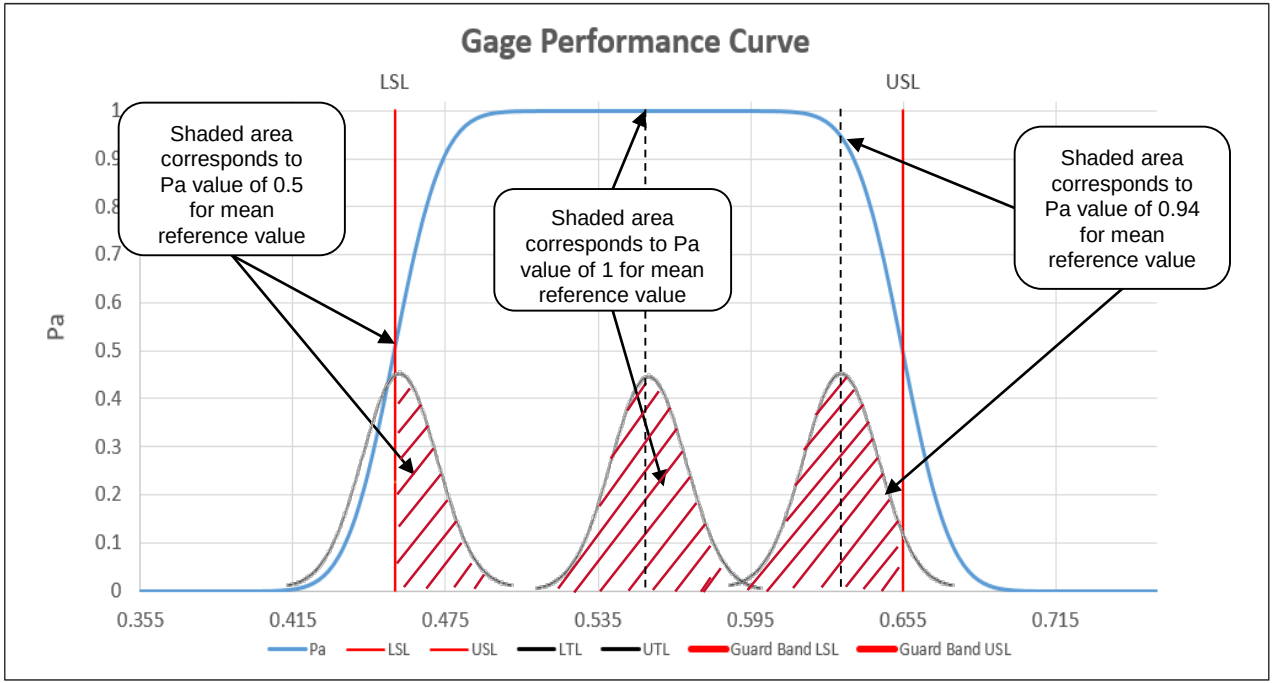

How do you address the risk of misclassification?

→ through Guard Banding

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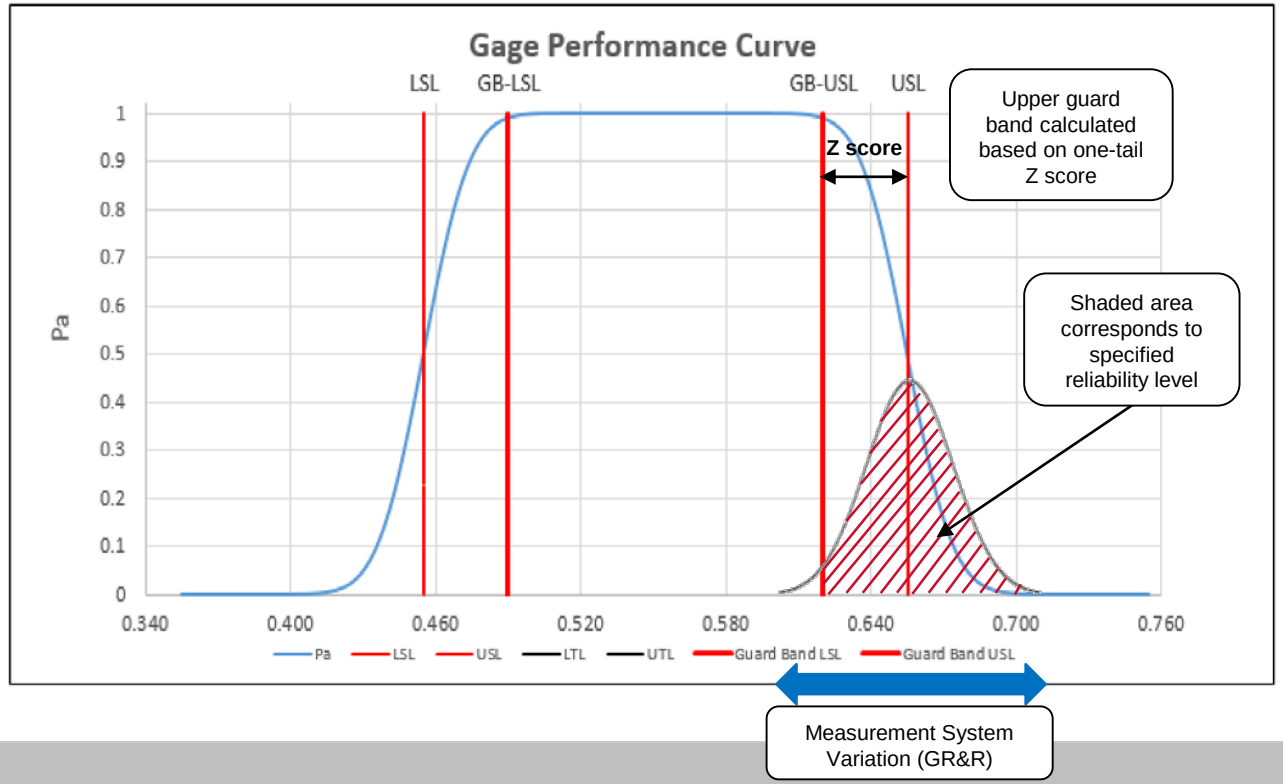
Guard Banding

Guard Banding Excel Tool – email me at gabor.attila.szabo@gmail.com to get a copy

- Guard band applied around specification limits
- Guard band width a fraction of measurement system variation

Guard Banding	
Guard Banding	Yes
Reliability	99%
Guard banded LSL	0.48995
Guard banded USL	0.62005



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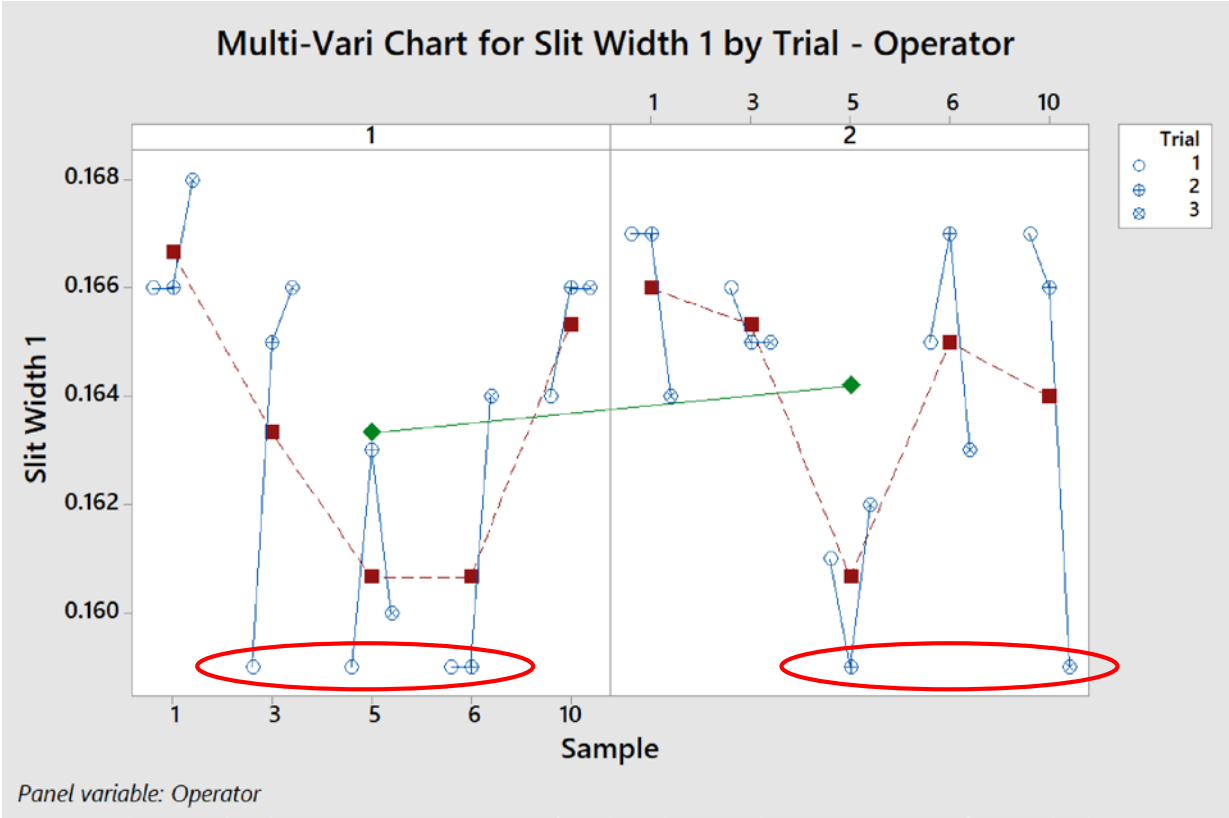
Examples

#1

Is there anything about the charted data that stands out?



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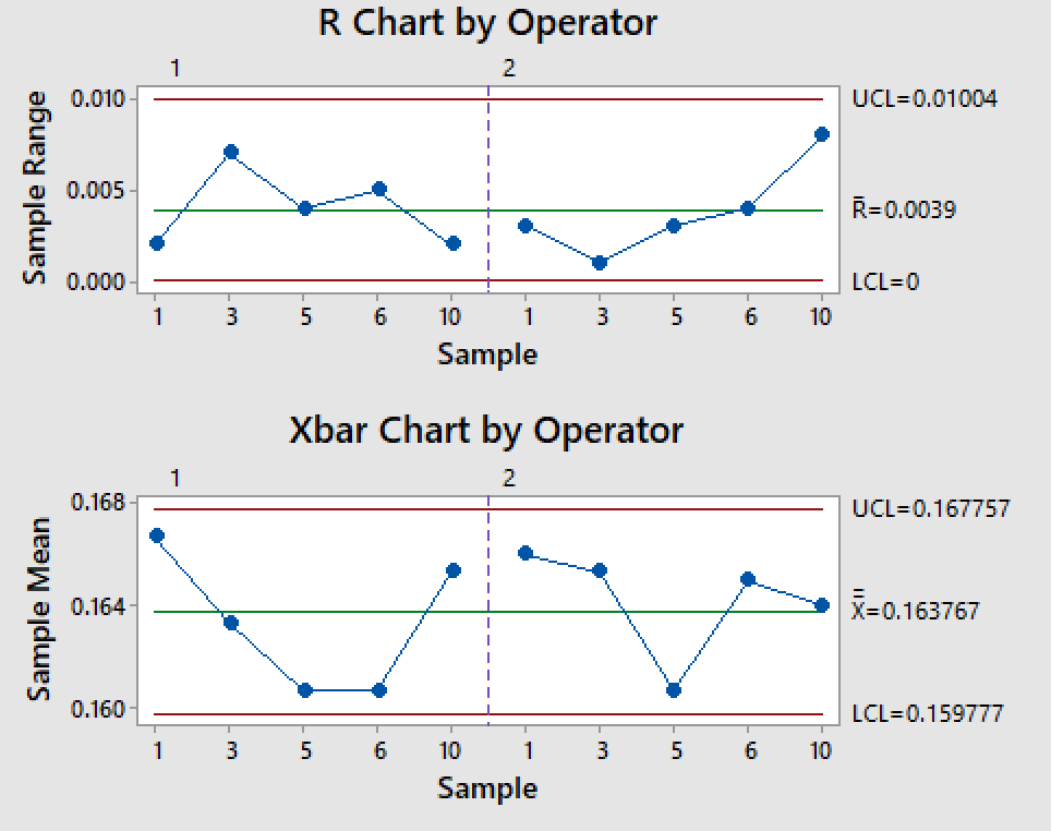
Examples

#1

- R chart: none of the ranges appear to be above the UCL
- Repeatability error exceeds part-to-part variation

Next steps:

- Investigate and eliminate special causes
- Assess whether further reduction of repeatability error is necessary



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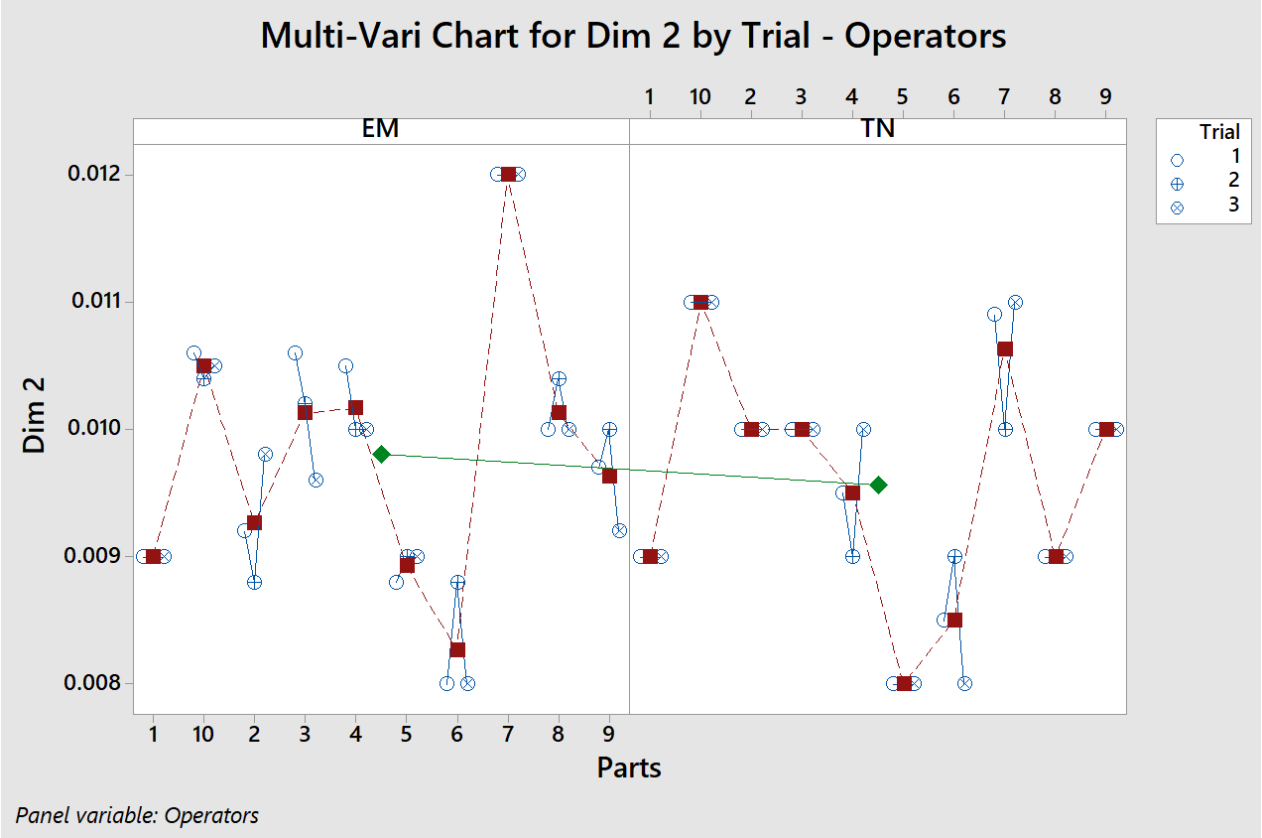
Examples

#2

Is there anything about the charted data that stands out?



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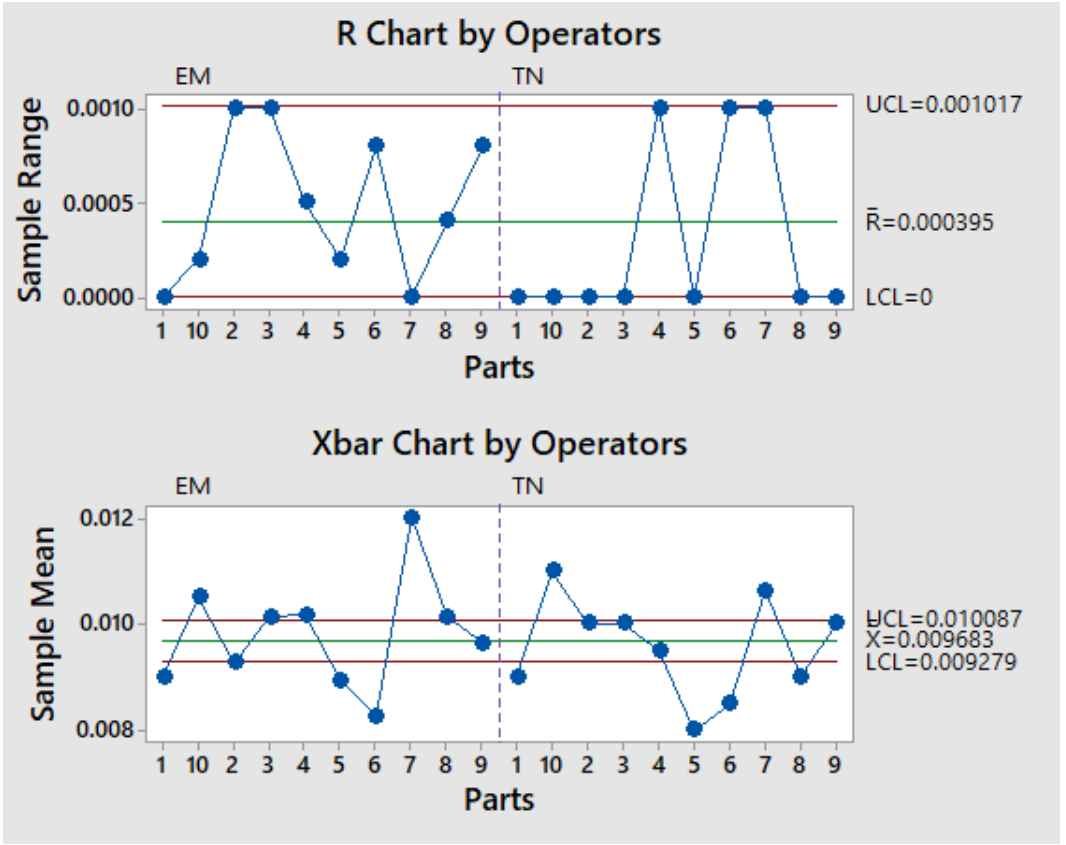
Examples

#2

- Resolution issue
- One of the operators (TN) rounded/truncated their measurement results

Next steps:

- Re-do study without rounding measurements
- Re-evaluate results



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Examples

#3

Is there anything about the raw data that stands out?

Sample	Trial	Operator	Dimension
1	1	1	0.04121
1	2	1	0.04119
1	3	1	0.04115
1	4	1	0.04112
2	1	1	0.04138
2	2	1	0.04134
2	3	1	0.04128
2	4	1	0.04127
3	1	1	0.04114
3	2	1	0.04112
3	3	1	0.04109
3	4	1	0.04108
1	1	2	0.04120
1	2	2	0.04116
1	3	2	0.04114
1	4	2	0.04110
2	1	2	0.04113
2	2	2	0.04111
2	3	2	0.04102
2	4	2	0.04101
3	1	2	0.04138
3	2	2	0.04137
3	3	2	0.04135
3	4	2	0.04131

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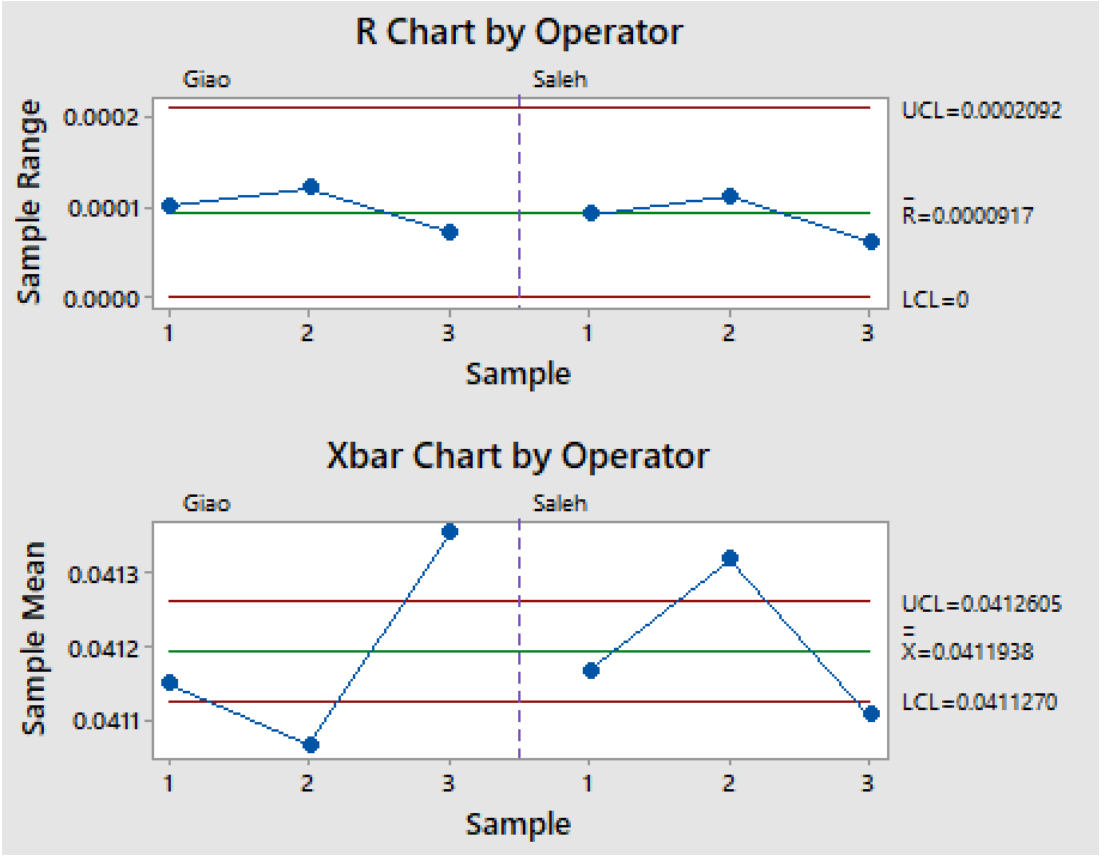
Examples

#3

Is there anything about the charted data that stands out?

- R chart: none of the ranges appear to be above the UCL
- Repeatability error does not exceed part-to-part variation



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Examples

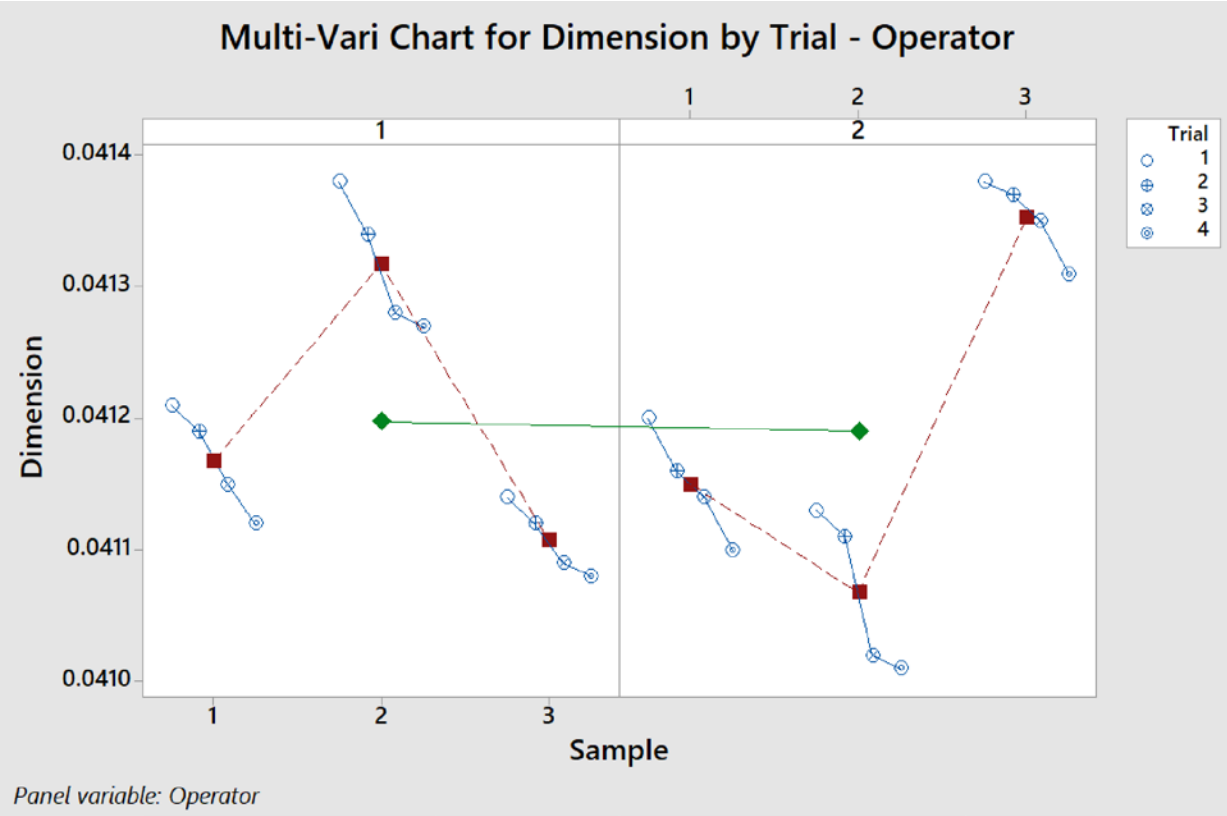
#3

Is there anything about the charted data that stands out?

- Decreasing pattern trial-to-trial

Next steps:

- Investigate the physics of the measurement or manufacturing process
- Investigate potential root causes



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Takeaways

- Don’t rely solely on your conventional Gage R&R metrics to tell you how your measurement system is behaving
- Use the Practical-Graphical-Analytical (PGA) approach to study your measurement systems analysis result, look for patterns and take action based on findings
- Quantify risks associated with measurement error

Feel free to reach out with any questions!

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