How to do a Gage R&R when you can’t do a Gage R&R

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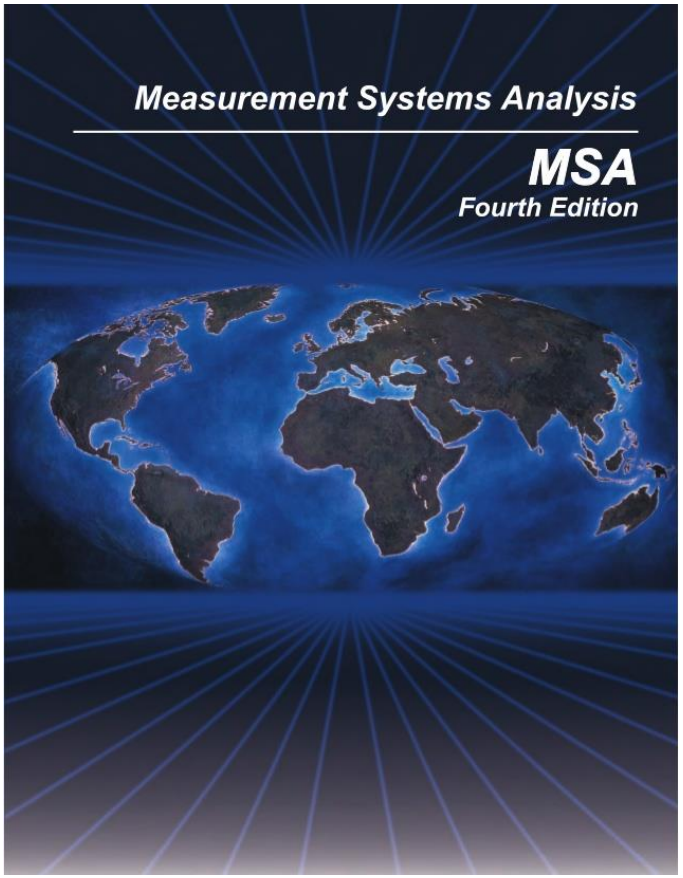
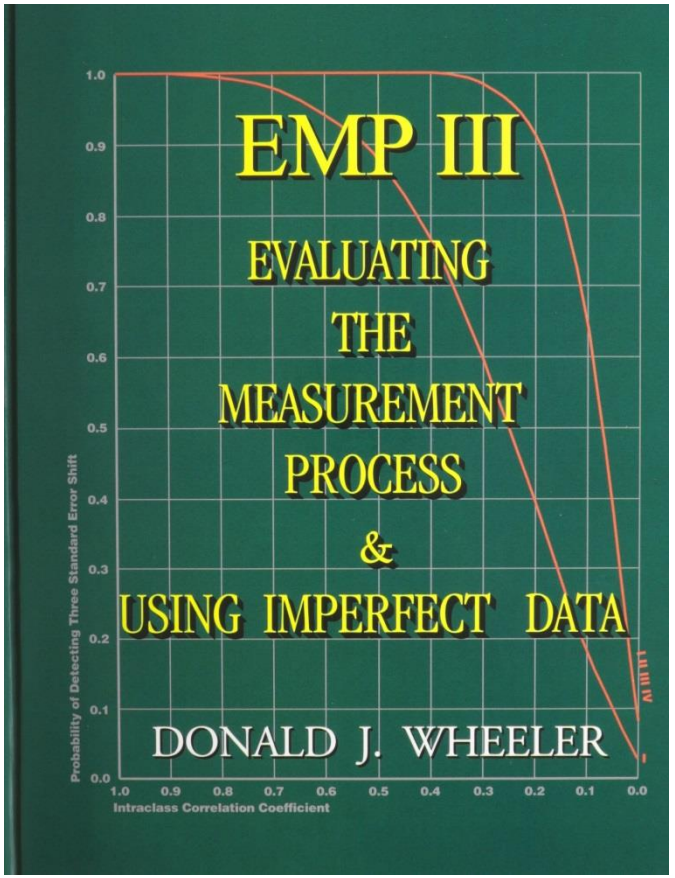
References





What are you Measuring

Measurement Process Error

- **The Model**

Product Measurements = Product Values + Measurement Errors

$$X = P + E$$

$$\mu_X = \mu_P + \mu_E$$

$${\sigma_X}^2 = {\sigma_P}^2 + {\sigma_E}^2$$

- **Measurement Errors**
  - Consistency – Predictability of a measurement process
  - Bias – Mean of consistent measurement process
  - Precision – Variation of a consistent measurement

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Ask the Right Questions!

- Is my measurement system returning **accurate**, **repeatable**, and **reproducible** results **representing** the characteristic I am interested in understanding?

Gage R&R Calculations

- Observed Process Variation

$$\sigma_X^2 = \sigma_P^2 + \sigma_E^2$$

- %GRR of Tolerance

$$\text{GRR \%Tol} = \frac{6 \cdot \sigma_{\text{ms}}}{\text{Tol Range}}$$

- %GRR of Process

$$\text{GRR \%SV} = \frac{6 \cdot \sigma_{\text{ms}}}{6 \cdot \sigma_{\text{Process}}}$$

AIAG General Guidelines of MSA Acceptability

GRR	Decision
Under 10 percent	Generally considered to be an acceptable measurement system.
10 percent to 30 percent	May be acceptable for some applications
Over 30 percent	Considered to be unacceptable

Table II-D 1: *GRR* Criteria

Destructive Testing

- Tensile Tests
- Pull Tests
- Bend Tests
- Burst Pressure
- Etc.

1- “Don’t Worry About It”

- If the observed process is stable and capable
  - The process variation and measurement system variation are individually stable and capable
  - The measurement system variation may be large compared to the process variation, but the process variation is small enough to compensate
  - A change in the process large enough to change the capability will be detected
- Requirements
  - SPC on the process and/or measurement
  - Measurement system should be evaluated if the process changes
  - Include a verification (largely different part) to ensure process is being measured

When beginning to evaluate an organization's measurement systems, it can be useful to set priorities on which measurement systems to initially focus. Since the final (total) variation is based on a combination of the process and measurement variation, ($\sigma_{Total} = \sqrt{\sigma^2_{Process} + \sigma^2_{MSA}}$), when SPC is being applied for process control or collecting process data, and the control chart indicates that the process is stable and the total variation is acceptable, the measurement system can be considered

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Chapter II – Section D
Analysis of the Results

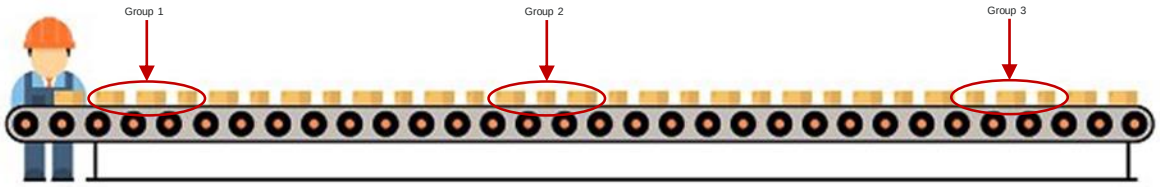
acceptable for this use and does not require separate re-evaluation[29]. If an out-of-control condition or nonconformance is found in this situation, the first thing that should be done is to evaluate the measurement system.

AIAG MSA Reference Manual Fourth Edition pp. 77-78

2- Consecutive Sampling

AIAG V3 and V3a method

- Select a group of consecutive parts with the least amount of variation possible:
  - Same component lots, operator, cavity, Etc.
- Collect multiple groups across the normal variation of the process
  - Different component lots, operators, cavities, Etc.
- Measure all of the parts in a random order with different appraisers
  - Each appraiser measures an equivalent number of parts from each group



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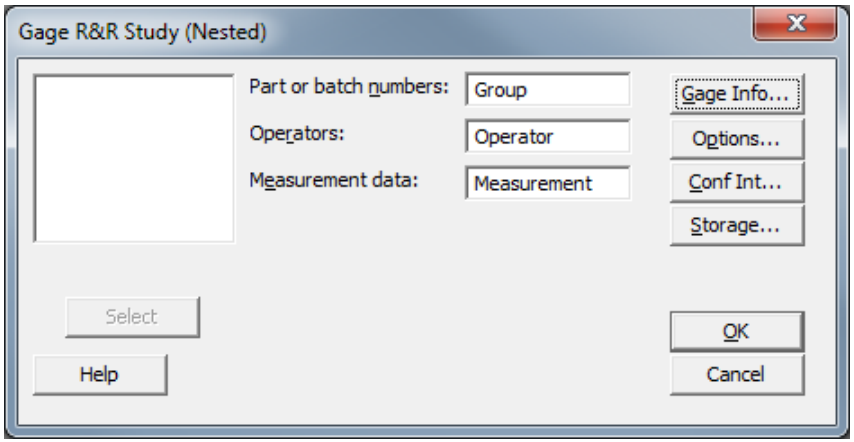
AIAG V3 and V3a method



Upper Bound

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Tolerance)
Total Gage R&R	0.21443	1.28661	20.21	12.87
Repeatability	0.21443	1.28661	20.21	12.87
Reproducibility	0.00000	0.00000	0.00	0.00
Part-To-Part	1.03923	6.23536	97.94	62.35
Total Variation	1.06112	6.36672	100.00	63.67

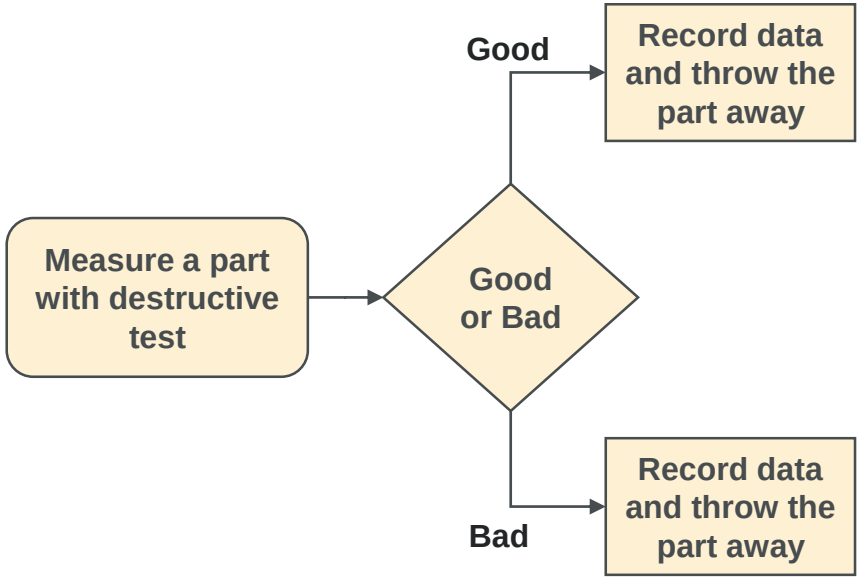
Number of Distinct Categories = 6

- Assume all of the group to be one part
- Complete a Gage R&R with the group identifier as the part identifier
  - Use a nested analysis to minimize the risk of assuming the group as a single part
- The resulting variation assigned to the measurement is actually a combination of the measurement system variation and the within group variation
  - %GRR result can be considered to be an upper bound

3- Lot / Batch Method

AIAG V4 method

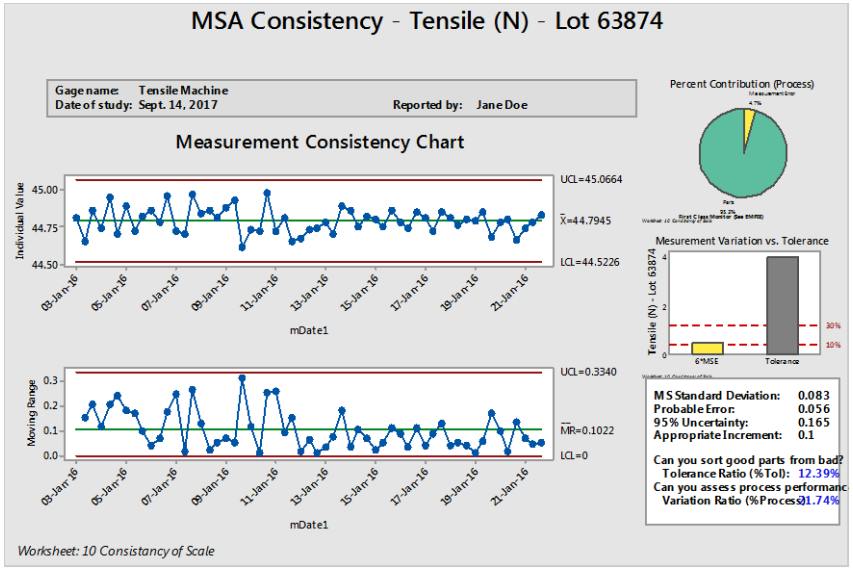
- Understand that one part represents a lot or batch of parts
- The characteristic being measured is the average and/or variation of that lot or batch
- Method is very similar to the Conventional Method, but the parts don’t need to be consecutive
- A part or Unit is a homogenous group or lot (this is not destroyed)



4- Consistency Chart

AIAG S3 method

- Collect a large group of parts from a homogenous set
  - One lot or batch
- Set aside and sample one or two on a periodic basis
- Graph periodic (i.e. daily) tests in a control chart
- If the data show stability, the measurement system is stable over time
- The pooled variation of the samples is a combination of the measurement system and the within lot/batch variation



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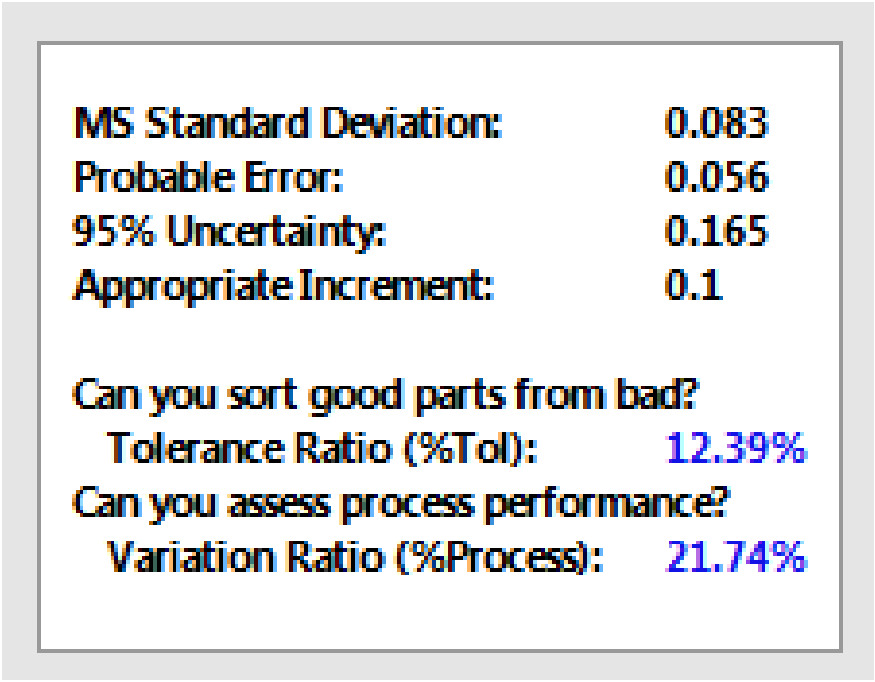
AIAG S3 method



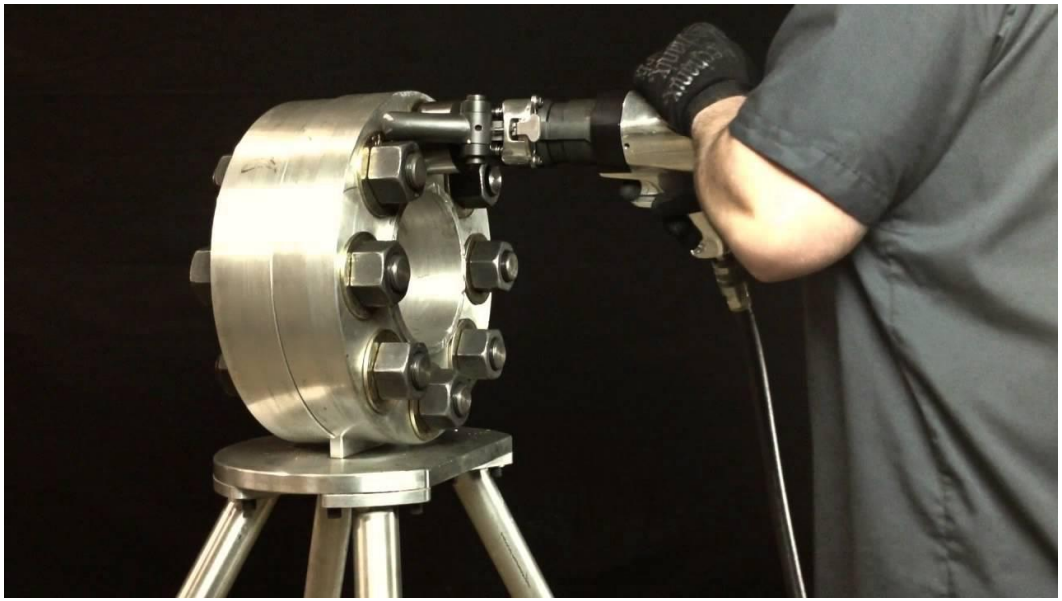
- A Destructive %GRR estimate will be larger than most measurement systems because it includes within lot/batch variation

- Using the measurements over time:
  - The measurement system variation can be estimated
  - The Probable Error and Uncertainty can be estimated to quantified
  - The appropriate increment (decimal places) can be determined
- Comparing the estimated variation:
  - To the tolerance, the %GRR of Tolerance can be estimated
  - To the process variation, the %GRR of Process can be estimated

Non-Replicable Machine Measurements

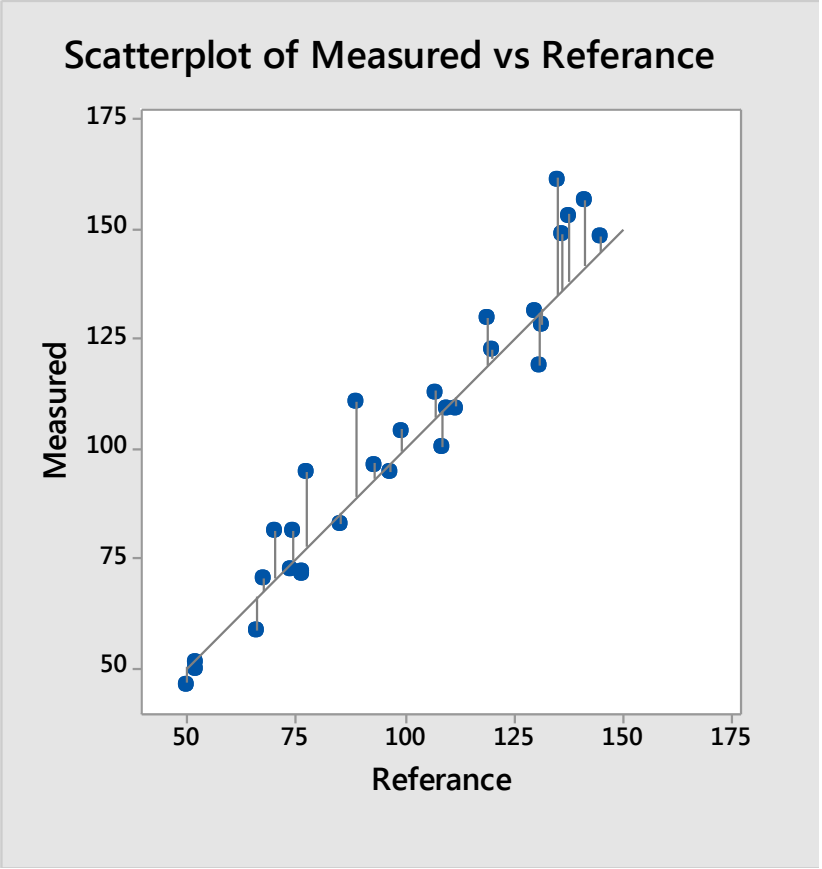
AIAG S3 method

- Examples
  - Crimp depth measured during process
  - Torque force of installing a nut
  - Installation depth
  - In-Line Measurements



5- Machine MSA
In-Line Measurements

- Another measurement system is needed as a reference
- Create parts and measure with both the system in question and the reference method
- Calculate the difference between the measured value and the reference value
- Evaluate the distribution of these differences



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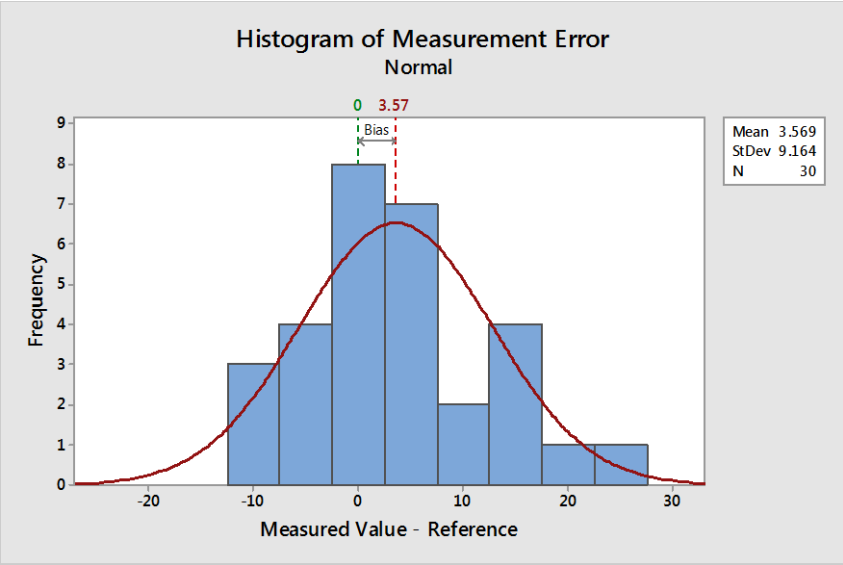
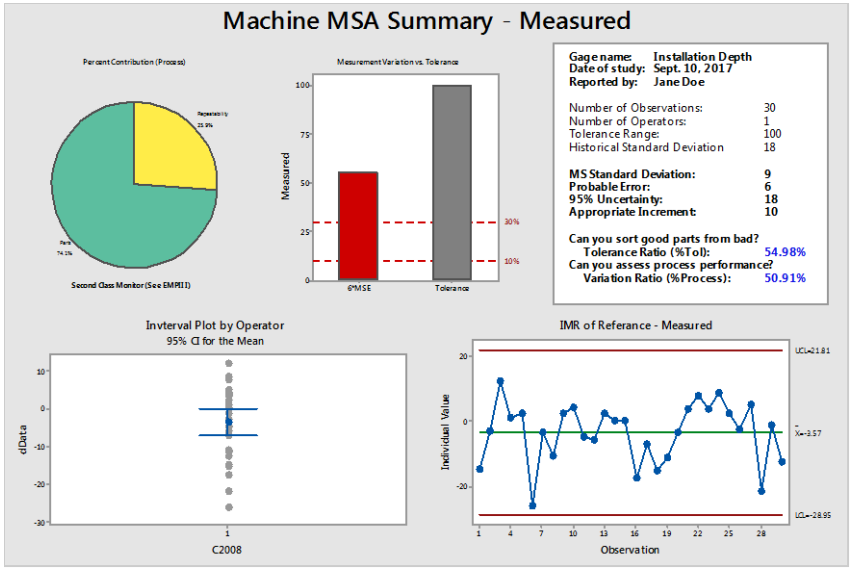
5- Machine MSA
In-Line Measurements



- The average deviation from the reference is the bias
- The variation of the deviations is the variation of the measurement system
  - If the reference measurement system also has significant variation, it can be subtracted from the measured variation
  - Quantify the reference variation with a GRR or equivalent

$$\sigma_{ms} = \sqrt{\sigma^2_{delta} - \sigma^2_{ref}}$$

5- Machine MSA
In-Line Measurements

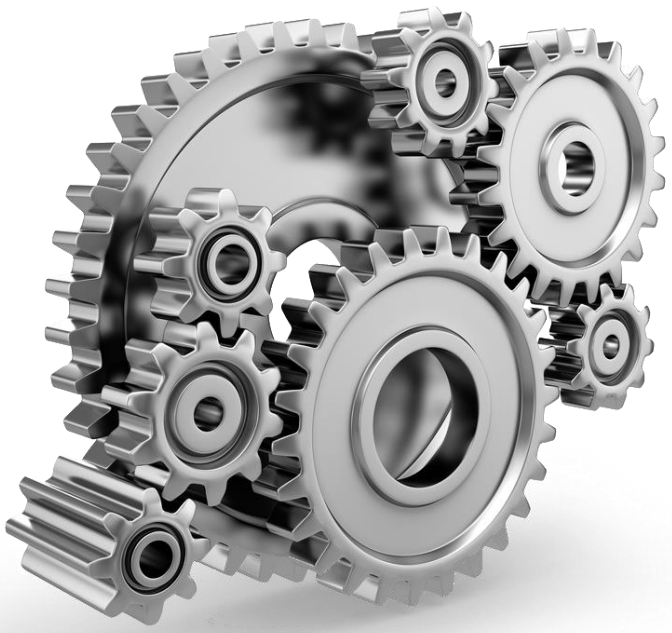


- The %GRR to Tolerance and the %GRR to Process can also be calculated

Gage name:	**Installation Depth**
Date of study:	**Sept. 10, 2017**
Reported by:	**Jane Doe**
Number of Observations:	30
Number of Operators:	1
Tolerance Range:	100
Historical Standard Deviation	18
MS Standard Deviation:	**9**
Probable Error:	**6**
95% Uncertainty:	**18**
Appropriate Increment:	**10**
Can you sort good parts from bad?	
Tolerance Ratio (%Tol):	**54.98%**
Can you assess process performance?	
Variation Ratio (%Process):	**50.91%**

6- Multi-Point GRR

- Measuring multiple points or characteristics on the same component
- Characteristics are not correlated or not being evaluated in multi-variate
- Same measurement system evaluates all points or characteristics

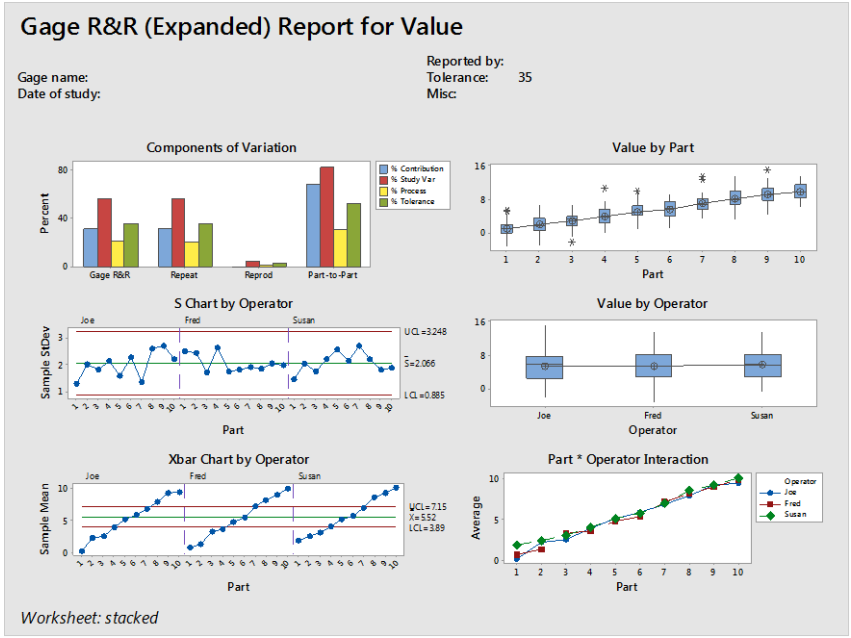


6- Multi-Point GRR

- Collect points from all characteristics
- Stack points of similar characteristics
- Evaluate in Expanded Gage R&R
- Check for equal variance of the measurement variation

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)	%Process (SV/Proc)
Total Gage R&R	2.08338	12.5003	56.34	35.72	20.83
Repeatability	2.07720	12.4632	56.17	35.61	20.77
Reproducibility	0.16045	0.9627	4.34	2.75	1.60
Operator	0.15454	0.9272	4.18	2.65	1.55
Point	0.04315	0.2589	1.17	0.74	0.43
Part-To-Part	3.05546	18.3328	82.62	52.38	30.55
Part	3.05546	18.3328	82.62	52.38	30.55
Total Variation	3.69815	22.1889	100.00	63.40	36.98



Conclusions

- Destructive Testing
  1. Don’t Worry about it
  2. Consecutive Sampling
  3. Lot / Batch Method
  4. Consistency
- In-Line Measurements
  5. Machine MSA
- Multi-Point
  6. 6- Multi-Point GRR

Questions