"GAUGE REPEATABILITY AND REPRODUCIBILITY (GR&R)"

QUALITY TOOLS

Description of GR&R

Gauge Repeatability and Reproducibility (GR&R) is one of the tools in Measurement System Analysis (MSA) to assess precision errors. Precision is the degree to which repeated measurements under the same conditions show the same results.

A GR&R study involves taking one part and measuring it several times, by several different people. Given that the part remains unchanged, any variation in measurement indicates the Repeatability of the gauge and Reproducibility of the measurements by different people. This process is repeated on several different parts to assess the result.

There are two main types of GR&R: 1) Continuous GR&R utilized for continuous data resulting from measuring a product or service characteristic such as length, weight, pressure, temperature, etc.; 2) Attribute GR&R applied for attribute data arising from classifying things such as good/bad, pass/fail, on time/late, etc.

For simplicity, discussion will be focused on Continuous GR&R although the same principle applies to Attribute GR&R.

When to use GR&R

1) Before a measuring equipment is issued for use
2) Routine check to ensure measuring equipment has not degraded
3) If measurement data is suspected to inaccurate
4) When a sound measurement system is required such as before implementing SPC or before conducting designed experiments
5) After repair of the measuring equipment
6) In a six sigma project, during the Measure phase where the quality of the data is evaluated before any measurement and analysis are conducted
7) To measure the need for training in how to use measuring instrument

How to use GR&R

It is not the absolute level of GR&R that is important but the relative level. The acceptability of GR&R results is assessed on the ratio (expressed as %) of the GR&R variation to the process (part to part) variation and to the customer tolerance. Typical acceptability criteria for both ratios are:

Marginal= < 30%
Good = < 20%
Excellent = < 10%

The steps involved in a GR&R study are outlined below:

1) Select part samples

This is the most critical step in performing a GR&R. Select samples that represent the true variation of the process. If necessary, samples are collected over a period of days or weeks to get samples that represent the process. Minimum sample size is 5 but ideal is 10 pieces to be measured three times by three different persons resulting to 90 measurements.

2) Label samples 1 to 10

Samples should be measured in random order if possible.

3) Measure samples

The minimum number of trials per appraiser is two, ideal is three. Have the appraiser measure the 10 samples in random order two or three times. Repeat for the next two appraisers.

4) Calculate % GR&R

This can be accomplished using statistical software like Minitab. Minitab utilizes ANOVA (Analysis of Variance) to show the part-to-part and operator-to-operator variations as well as part-operator interaction. If Minitab is not available, free excel spreadsheets are available online.

5) Determine acceptability

Use the acceptability criteria above to determine if the measurement system is acceptable

6) Take action

If the % GR&R is not acceptable, options available include leave as is and accept the risk or improve the measurement system.

Tips on use of GR&R

1. The measurement system should not be altered or adjusted for the GR&R otherwise it does not represent normal condition.
2. Use “actual” production parts and properly mark samples.
3. It is important to select appraisers who routinely use the measuring equipment rather than engineers or quality professionals.
4. Samples should be randomly measured and ideally “anonymous” to the appraiser to prevent any bias.

Application of GR&R

Below is a sample of a GR&R study from http://asq.org/sixsigma/2008/10/gage-r-r-with-anova-xbarr-analysis.html?shl=088720

Gage R&R for Outside Diameter

Gage Name:	Shaft Gage	**Part No. & Name:**	123456, Shaft	**Upper Tolerance:**	30
Date:	01/01/1980	**Gage No.**	1234	**Lower Tolerance:**	20
Performed by:	BOB	**Gage Type:**	Indicator	**Total Tolerance:**	10

Gage R&R Study - ANOVA Method

Variance and Standard Deviation Components

Source	St. Dev.	Variance	% of Variance
Total Gage R&R	1.03905	1.07963	19.00%
Repeatability	0.86734	0.75229	13.24%
Reproducibility	0.57214	0.32735	5.76%
Operator	0.50862	0.2587	4.55%
Operator*Part	0.26201	0.06865	1.21%
Part to Part	2.14509	4.60142	81.00%
Total Variation	2.3835	5.68106	100.00%

Process Tolerance = 10

Gage R&R Using 5.15 Standard Deviations (99%)

Source	Study Variation	% Study Variation	% of Tolerance
Total Gage R&R	5.35113	43.59%	53.51%
Repeatability	4.46683	36.39%	44.67%
Reproducibility	2.94654	24.00%	29.47%
Operator	2.61941	21.34%	26.19%
Operator*Part	1.34936	10.99%	13.49%
Part to Part	11.0472	90.00%	110.47%
Total Variation	12.275	100.00%	122.75%

Gage R&R Using 6.0 Standard Deviations (99.7%)

Source	Study Variation	% Study Variation	% of Tolerance
Total Gage R&R	6.23433	43.59%	62.34%
Repeatability	5.20407	36.39%	52.04%
Reproducibility	3.43286	24.00%	34.33%
Operator	3.05174	21.34%	30.52%
Operator*Part	1.57207	10.99%	15.72%
Part to Part	12.8706	90.00%	128.71%
Total Variation	14.301	100.00%	143.01%

Number of Distinct Categories = 2

Analysis of Variance (ANOVA) Table

Source	DF	SS	MS	F	p
Part	9	381.339	42.371	44.218	0.000
Operator	2	17.4383	8.71916	9.099	0.002
Op.x Part Interaction	18	17.2483	0.95824	1.274	0.238
Gage (error)	60	45.1372	0.75229		
Total	89	461.163			

p value for Op. x Part Interaction as error term = 0.25

Gage R&R Study - Xbar/Range Method

Variance and Standard Deviation Components

Source	St. Dev.	Variance	% of Variance
Total Gage R&R	0.9859	0.972	16.92%
Repeatability	0.8327	0.69339	12.07%
Reproducibility	0.5278	0.27857	4.85%
Part to Part	2.1848	4.77335	83.09%
Total Variation	2.3969	5.74513	100.00%

Process Tolerance = 10

Gage R&R Using 5.15 Standard Deviations (99%)

Source	Study Variation	% Study Variation	% of Tolerance
Total Gage R&R	5.07739	41.13%	50.77%
Repeatability	4.28841	34.74%	42.88%
Reproducibility	2.71817	22.02%	27.18%
Part to Part	11.2517	91.15%	112.52%
Total Variation	12.344	100.00%	123.44%

Gage R&R Using 6.0 Standard Deviations (99.7%)

Source	Study Variation	% Study Variation	% of Tolerance
Total Gage R&R	5.9154	41.13%	59.15%
Repeatability	4.9962	34.74%	49.96%
Reproducibility	3.1668	22.02%	31.67%
Part to Part	13.1088	91.15%	131.09%
Total Variation	14.3814	100.00%	143.81%

Number of Distinct Categories = 3

For template follow the link: http://asq.org/sixsigma/2008/10/gage-r-r-with-anova-xbarr-analysis.html?shl=088720

References

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http://chartitnow.com/R&R.html
http://www.qualitytrainingportal.com/resources/msa/grr.htm
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