Shaft Diameter: Consistency Study

Description of Output

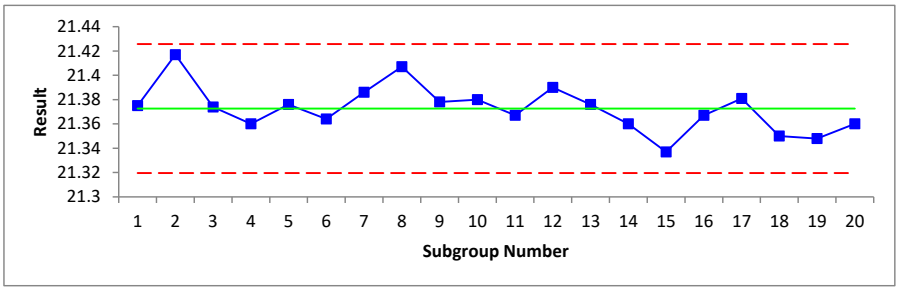
Gage: P-1045
Characteristic: Diameter
Process Avg.:
Process Sigma: 0.035

USL: 21.475
LSL: 21.325
Measurement Increment: 0.001
Reference Value: 21.45

Print out of information entered by the user

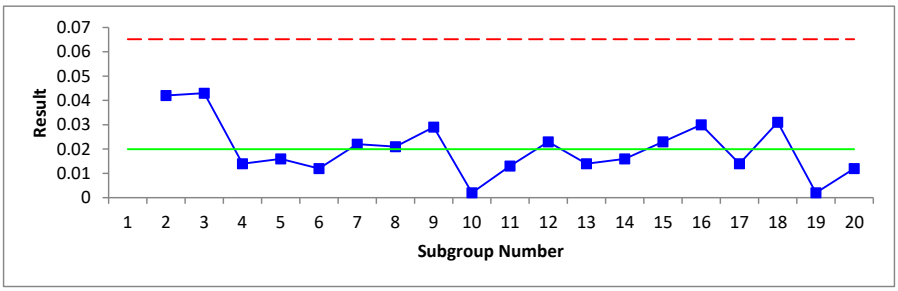
X and Moving Range Control Charts

X Chart



The X chart is a plot of the results each time the same sample/part is measured. The average, upper control limit and lower control limit are calculated and plotted on the chart.

Moving Range (mR) Chart



The moving range chart is a plot of the range between consecutive results on the X chart. This moving range is a measure of the repeatability of the test method. The average and upper control limit are calculated and plotted on the chart.

Control Chart Calculations

$\bar{X}$	UCLx=$\bar{X}$ + 2.66(m$\bar{R}$)	LCLx=$\bar{X}$ - 2.66(m$\bar{R}$)
21.3727	21.4257	21.3196

m$\bar{R}$	UCLr=3.27(m$\bar{R}$)
0.0199	0.0652

The control chart calculations are given.

X Chart Analysis

Consistency Analysis

The X chart should not have any out of control points.
Out of control points are indications that there are special causes present.

There are no out of control points on the X chart.
The measurement values are consistent.

The X chart is analyzed. There should be no out of control points. If there are, the reason should be found and removed; then the study should be repeated. The information in italics are the conclusions from the X chart analysis.

Bias (Reference Value = 21.45)

99% LCL	90% LCL	Average	90% UCL	99% UCL
21.3605	21.3653	21.3727	21.3800	21.3848

The reference value lies outside the 99% confidence interval limits.
There is detectable bias in the measurement system.

If a reference value (RV) s entered, a check for bias is made using confidence intervals (CI). If the RV is between the 90% CI, there is no bias; if between 90% and 99% CI, there may be bias; if RV is beyond the 99% CI, there is detectable bias present.

Moving Range Chart Analysis

Consistency Analysis

Each moving range value is a measure of the repeatability (test-retest error).
The moving range chart should not have any out of control points.
Out of control points are indications that there are special causes present.

There are no out of control points on the range chart.
The ranges are consistent.
The repeatability (test-retest error) calculation below is valid.

The mR chart is analyzed. There should be no out of control points. If there are, the reason should be found and eliminated and then the study repeated. The information in italics are the conclusions from the mR chart analysis.

Amount of Data

There are 11.9 degrees of freedom associated with the average moving range.
It is recommended to have at least 10 degrees of freedom.

The study should contain sufficient data (degrees of freedom). This is checked here.

Chunkiness

There are 66 possible values within the range chart.
There is no sign of chunkiness (e.g. excessive rounding) in the data.

A check is made to ensure there is not chunky data which can lead to false signals on a control chart.

Repeatability (Test-Retest Error)

$\sigma_{pe}=m\bar{R}/1.128$

0.0177

The repeatability (standard deviation) of the test method is determined from the average range.

Probable Error (PE) and Measurement Increment

PE	0.0119	Probable Error ($0.675\sigma_{pe}$)
0.2(PE)	0.00239	Smallest Effective Measurement Increment
2(PE)	0.0239	Largest Effective Measurement Increment

PE is the minimum medium error of the measurement process.
50% of the measurements will fall within +/- one PE.
PE defines the effective resolution of the measurement process.
The resolution should be between 0.2(PE) and 2(PE).

The measurement increment (0.001) is less than 0.2(PE),
increase the measurement increment so it is between 0.2PE and 2PE.

The probable error (PE) is calculated to determine if the measurement increment is adequate. The measurement increment should be between 0.2PE and 2PE. If the measurement increment is too small, round up and rerun the analysis. If it is too large, look at ways to decrease the measurement increment.

Watershed Specifications[1] and Precision to Tolerance Ratio

Watershed USL =	21.4755
Watershed LSL =	21.3245
Watershed Tol. =	0.151

% Mfg. Specs[2]	*PE Used to Tighten Specs*[3]	*Mfg. LSL*[4]	*Mfg. USL*[4]	*Precision to Tolerance Ratio*[5]
85.0%	1	21.3364366	21.4635634	15.81%
96.0%	2	21.3483732	21.4516268	31.62%
99.0%	3	21.3603098	21.4396902	47.43%
99.9%	4	21.3722464	21.4277536	63.24%

[1]Watershed specification limits take into account the measurement increment.
Watershed USL = USL + 0.5(measurement increment)
Watershed LSL = LSL - 0.5(measurement increment)
Watershed Tolerance = Watershed USL - Watershed LSL

[2]*% Mfg Specs* is the probability that an item, with a measured value that falls between the Mfg. LSL and Mfg. USL, conforms to specifications.

[3]*PE Used to Tighten Spec* s is the number of PE units used to reduce the watershed specifications.

[4]*Mfg. LSL* and *Mfg. USL are* the specifications based on the PE adjustments.
Example: 96%, Mfg. LSL = Watershed LSL + 2(PE) and Mfg. USL = Watershed USL - 2(PE)

[5]*Precision to Tolerance Ratio* is the % of the watershed tolerance consumed by the PE adjustment.
Example: For 96% Mfg. Specs, P/T = 4(PE)/Watershed Tolerance

If at least one specification is entered, the watershed specifications and precision to tolerance ratio are determined. The watershed specifications are used to determine manufacturing specifications that take into account measurement error (probable error).

The precision to tolerance ratio describes the % of the tolerance that is consumed by the probable error adjustment to the watershed specifications.

Overall Variance and Product Variance

Assumption: process sigma entered represents variation in the production process.

Process Sigma	0.035	σ_x
Total Variance	0.00123	σ_x^2
Product Variance	0.000912	$\sigma_p^2 = \sigma_x^2 - \sigma_{pe}^2$

Summary	**Variance**	**% of Total**
Measurement	0.000313	25.53%
Product	0.000912	74.47%
Total	0.00123	

If the process sigma is entered, it is used to determine the total variance and the product variance. The measurement and product variances as a % of the total variance can then be determined.

Intraclass Correlation Coefficient (ρ_{pe})

$\rho_{pe} = \sigma_p^2/(\sigma_p^2+\sigma_{pe}^2)$ = 0.7447

If the process sigma is entered, the intraclass coefficient is calculated. This is used to determine the type of monitor below.

Type of Class Monitor

ρ_{pe}	**Type of Monitor**	**Reduction of Process Signal**[a]	**Chance of Detecting ± 3 Std. Error Shifts**[b]	**Ability to Track Process Improvements**[c]
0.8 to 1.0	First Class Monitor	Less than 10%	>99% with Rule 1	
0.5 to 0.8	Second Class Monitor	From 10% to 30%	>88% with Rule 1	Up to Cp50 = 1.006
0.2 to 0.5	Third Class Monitor	From 30% to 55%	>91% with Rules 1, 2, 3, & 4	Up to Cp20 = 1.273

If the process sigma in entered, the type of class monitor is determined. The row for the class

0.0 to 0.2	Fourth Class Monitor	Greater than 55%	Rapidly Vanishes	Unable to Track

monitor is highlighted in yellow. If one or more specification is entered, the various Cp values are determined.

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[a]A signal occurring on a control chart is reduced in strength by 1 - square root of ρ_o.

[b]The probability that the measurement process can detect a significant shift.
Rule 1: Point beyond the control limits.
Rule 2: 2 out of 3 consecutive points on the same side of the average are > 1 sigma from the average.
Rule 3: 4 out of 5 consecutive points on the same side of the average are > 2 sigma from the average.
Rule 4: 8 consecutive points on the same side of the average.

[c]The process capability where the measurement process will move down to a lower class.

Data

Optional Data Table

Sample ID	X	Comments
1	21.375	
2	21.417	
3	21.374	
4	21.36	
5	21.376	
6	21.364	
7	21.386	
8	21.407	
9	21.378	
10	21.38	
11	21.367	
12	21.39	
13	21.376	
14	21.36	
15	21.337	
16	21.367	
17	21.381	
18	21.35	
19	21.348	
20	21.36	