

Module 2 : Histogram & Capability Analysis

7 QC Tools (2 days)

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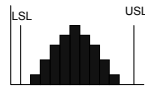
Histograms

What is it?

- A Histogram is a bar graph
- usually used to present frequency data

How does it Work?

- Define Categories for Data
- Collect Data, sort them into the categories
- Count the Data for each category
- Draw the Diagram. each category finds its place on the x-Axis.
- The bars will be as high as the value for the category



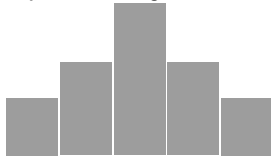
What does the histogram do?

- Displays large amounts of data that are difficult to interpret in tabular form
- Shows the relative frequency of occurrence of the various data values
- Reveals the centering, variation, and shape of the data
- Helps to indicate if there has been a change in the process
- Helps to answer the question " Is the process capable of meeting requirement?"

Interpretation –Capability Analysis

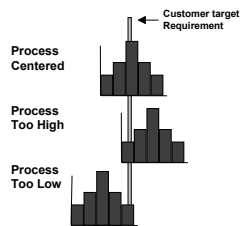
- Shows the relative frequency of occurrence of the various data values
- Reveals the centering, spread, and shape of the data
- Helps to indicate if there has been a change in the process
- When plotted against specifications it is one of the best ways to assess capability. It can answer the question,

“Is the process capable of meeting the customer requirements?”



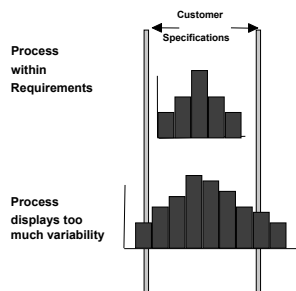
Interpretation - Histogram

- How well is the histogram centered?
 - The centering of the data provides information on the process aim about some mean or nominal value.



Interpretation - Histogram

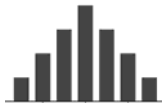
- How wide is the histogram?
 - Looking at histogram width defines the variability of the process about the aim.



What is the shape of the histogram?

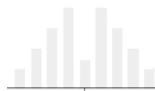
- Remember that the data is expected to form a normal or bell-shaped curve. Any significant change or anomaly usually indicates that there is something going on in the process which is causing the quality problem.

Normal Distribution



- Depicted by a bell-shaped curve
 - most frequent measurement appears as center of distribution
 - less frequent measurements taper gradually at both ends of distribution
- Indicates that a process is running normally (only common causes are present).

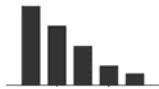
BI-MODAL Distribution



- Distribution appears to have two peaks
- May indicate that data from more than process are mixed together
 - materials may come from two separate vendors
 - samples may have come from two separate machines.

CLIFF-LIKE Distribution

- Appears to end sharply or abruptly at one end
- Indicates possible sorting or inspection of non-conforming parts.



COMB Distribution

- Also commonly referred to as a saw-toothed distribution, appears as an alternating jagged pattern
- Often indicates a measuring problem
 - improper gage readings
- gage not sensitive enough for readings

SKEWED Distribution

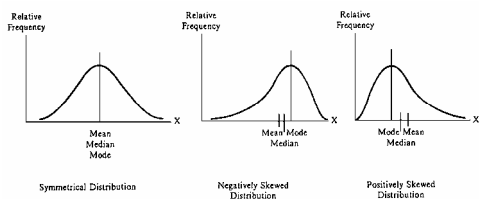
- Appears as an uneven curve; values seem to taper to one side.



Skewness

- The degree of asymmetry of a distribution around its mean is referred to as its skewness.
- Positive skewness implies a distribution with an asymmetric tail extending towards higher values.
- Sometimes referred to as *right-handed skew*.
- Negative skewness implies a distribution with an asymmetric tail extending towards lower values.
- Sometimes referred to as *left-handed skew*.

Skewness (cont.)



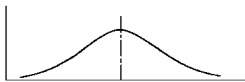
Skewness (cont.)

- If the data are symmetric, the mean and median will coincide. If the data is unimodal, then the mean, median and mode will all coincide.
- If the data are skewed, the mean, median and mode will not coincide.
- For right-handed skewness: $\text{mode} < \text{median} < \text{mean}$
- For left-handed skewness : $\text{mode} > \text{median} > \text{mean}$

Kurtosis Distribution

- Kurtosis characterizes the relative peakedness or flatness of a distribution compared to a normal (*mesokurtic*) distribution.
- Positive kurtosis indicates a relatively peaked (*leptokurtic*) distribution compared to the normal distribution.
- Negative kurtosis indicates a relatively flat (*platykurtic*) distribution compared to the normal distribution.
- Kurtosis is relevant only for symmetrical distributions.

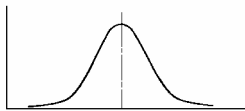
Kurtosis (cont.)



Mesokurtic curve
(meso-, meaning
"intermediate")



Platykurtic curve
(platy-, meaning
"broad" or "flat")



Leptokurtic curve
(lepto-, meaning
"slender")

Some important things to remember when constructing a histogram:

- Use intervals of equal length.
- Show the entire vertical axes beginning with zero.
- Do not break either axis.
- Keep a uniform scale across the axis.
- Center the histogram bars at the midpoint of the intervals

Capability Analysis

Capability Analysis Study

What is capability analysis study?

- Capability analysis study is a set of calculations used to assess whether a system is statistically able to meet a set of specifications or requirements.
- To complete the calculations, a set of data is required.

Process Capability Assumptions

- For valid process capability calculations, all data must be from an *in-control process*, with respect to both the mean and standard deviation.
- Make sure to check this data in a variables control chart to make sure that all points in the X bar, S or R charts are in control. If they aren't, your capability indices are not valid.
- The process must first be brought into statistical control by detecting and acting upon special causes of variation. Then its performance is predictable, and its capability to meet customer expectations can be assessed.

Potential versus Performance Capability

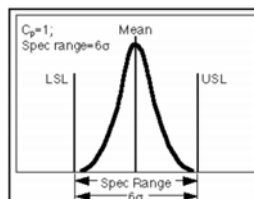
- Potential capability reveals what could happen if the process is properly centered and is said to possess potential capability if its 6 sigma spread is equal to (less than) the width of the tolerance.
- Performance capability measures how well the process output actually conforms to the specification
- Measures considering only process spread are called measures of potential capability, while those comprehending both spread and centering are designated measures of performance capability.

Two Groups of Capability Indices

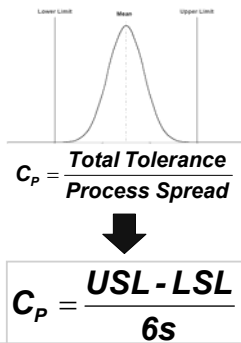
- C_p - Represents process capability - what the process potential is given a stable process
 - Standard deviation estimated from Moving Range or pooled standard deviation – represents common cause variation
- C_{pk} - Represents process performance - what has happened, not necessarily what will happen
 - Standard deviation estimated from the traditional formula – includes both common and special causes of variation

Process Capability (C_p)

- Assuming that the mean of the process is centered on the target value, the process capability index C_p can be used.
- C_p is a simple process capability index that relates the allowable spread of the spec limits (spec range or the difference between the upper spec limit, USL, and the lower specification limit, LSL) to the measure of the actual, or natural, variation of the process, represented by 6 sigma, where sigma is the estimated process standard deviation.



Potential Capability, C_p



Process Capability, C_p

- If the process is in statistical control, and the process mean is centered on the target, then C_p can be calculated as follows:

$$C_p = \frac{\text{Engineering Tolerance}}{\text{Natural Tolerance}} = \frac{USL - LSL}{6\sigma}$$

- $C_p < 1$ means the process variation exceeds specification, and a significant number of defects are being made.
- $C_p = 1$ means that the process is just meeting specifications. A minimum of 0.3% defects will be made and more if the process is not centered.
- $C_p > 1$ means that the process variation is less than the specification, however, defects might be made if the process is not centered on the target value.

Process Capability & Reject Rate

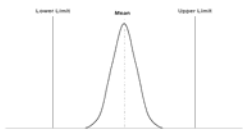
If the process is *centered* within its tolerance,

- C_p of 1.0 has indicated that 0.27% of parts produced will be beyond specification limits.
- C_p of 1.33 has indicated that 0.007% of parts produced will be beyond specification limits.

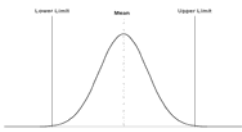
C_p	Reject Rate
1.00	0.270 %
1.33	0.007 %
1.50	6.8 ppm
2.00	2.0 ppb

C_p vs Specification Limits

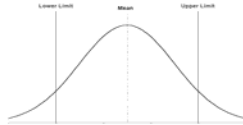
a) Process is highly capable



b) Process is marginally capable



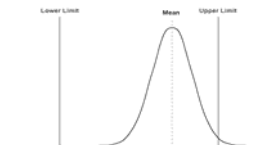
c) Process is not capable



Process Performance Index , C_{pk}

- C_{pk} measures not only the process variation with respect to allowable specifications, it also considers the location of the process average.
- It relates the scaled distance between the process mean and the nearest specification limit.

Performance Capability, C_{pk}

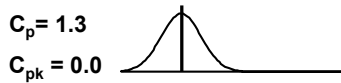


$$C_{pk} = \min\left(\frac{\bar{X} - LSL}{3s}, \frac{USL - \bar{X}}{3s}\right)$$

$$C_{pL} = \frac{\bar{X} - LSL}{3s}$$

$$C_{pU} = \frac{USL - \bar{X}}{3s}$$

Cp & Cpk for an Off-Center Process



Exercise

Specification Limits: 4 to 16 g

Machine	Mean	Std Dev
(a)	10	4
(b)	10	2
(c)	7	2
(d)	13	1

Determine the corresponding Cp and Cpk for each machine.

Process Capability vs Process Performance

Process Capability, C_p

- If the process is properly centered and is said to possess potential capability if its 6 sigma spread is equal to the width of the tolerance.
- Measures considering only process spread

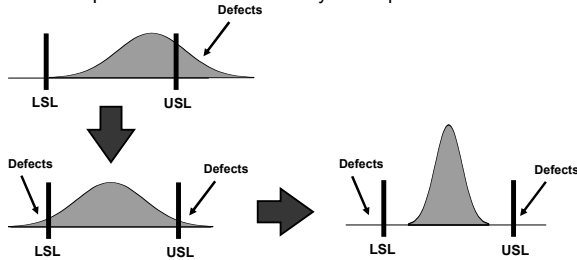
Process Performance Index, C_{pk}

- Measures how well the process output actually conforms to the specification
- Comprehending both spread and centering

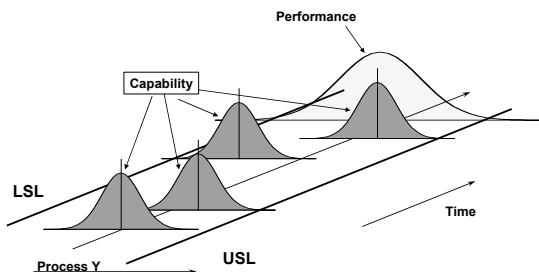
$$C_p - C_{pk} = \text{Missed Opportunity}$$

Process Capability - Strategy

1. "Centering" – Put the process on target
2. "Spread" – Reduce variability of the process



The Dynamic Process



Over time, a process tends to shift by approximately 1.5σ

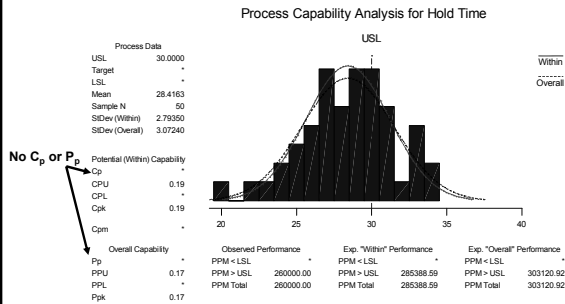
Six Sigma Capability

- For a process to be considered Six Sigma:
 - $C_p = 2.0$
 - If stable, the voice of the process is half the size of the customer specification
 - This means that if the process is centered, the mean is 6σ away from either specification limit
 - $P_{pk} = 1.5$
 - Accounts for 1.5σ shift and drift
- Note: Achieving a 6σ level of capability is not necessarily the goal of every project

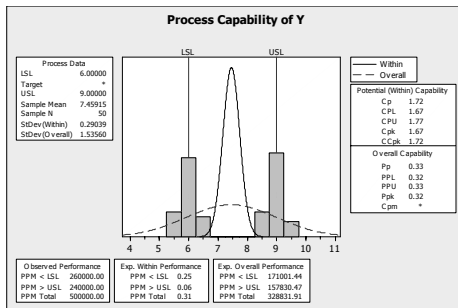
One-Sided Capability Analysis

- Customer requirements or goals are often one-sided
 - Examples:
 - Hold time < 30 seconds
 - Peel value > 6 lbs.
 - DSO < 45 days
- Capability analysis on these processes are similar to two-sided capability but can't provide all of the same information
 - C_p and P_p are not calculated because there is not a "range" for the customer requirements or goals
 - C_{pk} and P_{pk} are calculated the same

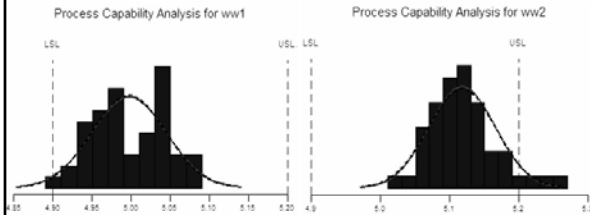
One-Sided Capability Example – Hold Time



Case Study 1 – Distribution



Case Study 2



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